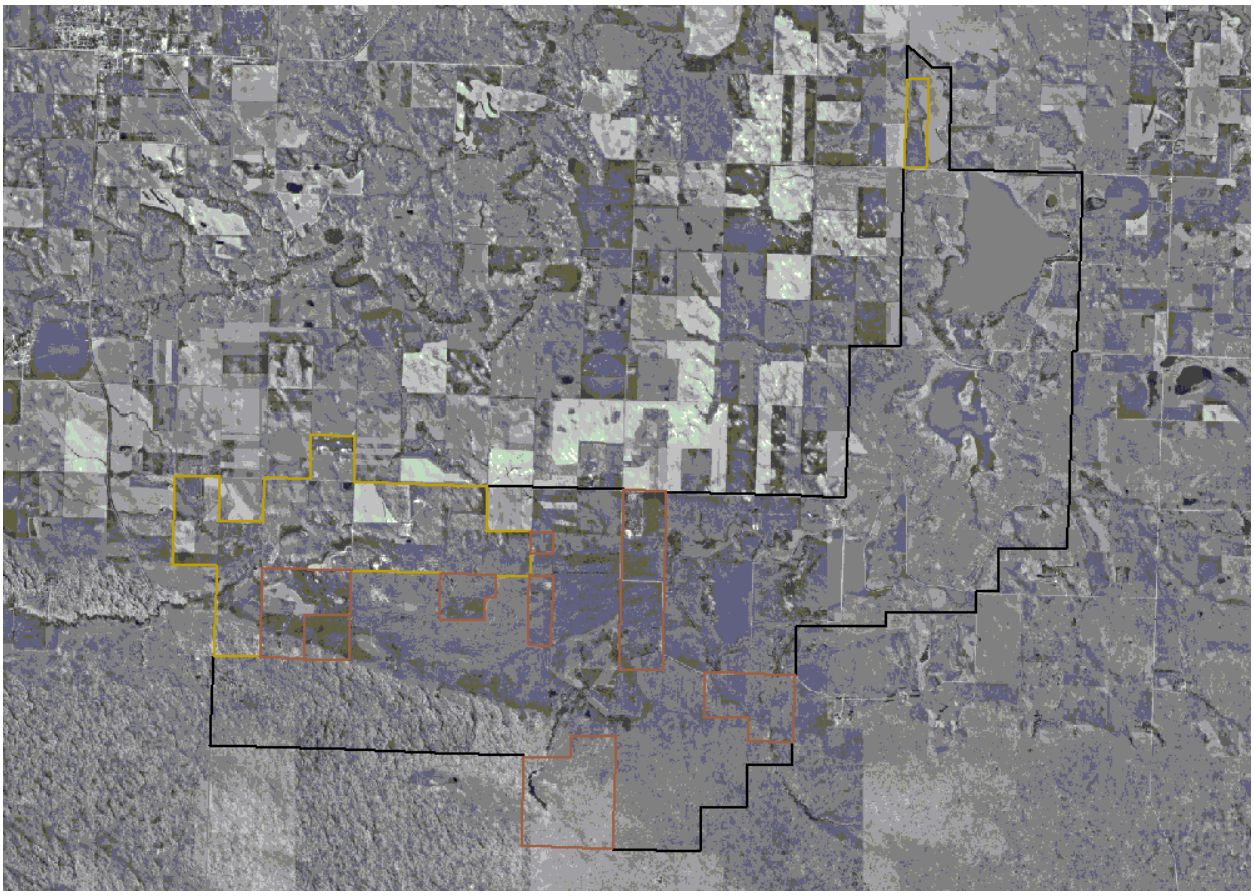
Lacreek National Wildlife Refuge, South Dakota
2000-2001 VEGETATION MAPPING PROJECT



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Technical Memorandum 8260-02-02
Remote Sensing and GIS Group
Technical Service Center
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Denver, CO

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The Remote Sensing and Geographic Information Group, organized in 1975, provides assistance and advice regarding the application of remote sensing and geographic information systems (GIS) technologies to meet the spatial information needs of the Bureau of Reclamation and other governmental clients.

This report was prepared for the U.S. Fish and Wildlife Service's Mountain-Prairie Region (Region 6) and the U.S. Geological Survey's Center for Biological Informatics by the Remote Sensing and GIS Group of the Bureau of Reclamation's Technical Service Center, Denver, CO as Technical Memorandum No. 8260-02-02.

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Adapting the USGS-NPS Vegetation Mapping Standards to the needs of National Wildlife Refuges required the dedicated and ingenious efforts of many individuals. The staff at Lacreek National Wildlife Refuge (LNWR) contributed in many ways to the completion of the project, including help with the initial organization and review of draft vegetation maps and vegetation classification. NatureServe helped complete the vegetation descriptions, while the USGS Center for Biological Informatics and the Region 6 office of USFWS provided overall program coordination. Last but hardly least, two individuals put in untold hours of fieldwork to collect data for the classification and for accuracy assessment, without their commitment this project would not have been possible.

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LIST OF ABBREVIATIONS AND ACRONYMS

AA	Accuracy Assessment
ABI	Association for Biodiversity Information (now NatureServe a TNC Affiliate)
AML	Arc Macro Language
BOR	Bureau of Reclamation (Also USBR)
BRD	Biological Resource Division (of the USGS)
CBI	Center for Biological Informatics (of the USGS/BRD)
CIR	Color Infra-Red Photography
DEM	Digital Elevation Model
DLG	Digital Line Graph
DRG	Digital Raster Graphic
DOQQ	Digital Orthophoto Quarter Quadrangles
FGDC	Federal Geographic Data Committee
FWS	Fish and Wildlife Service
LNWR	Lacreek National Wildlife Refuge
GIS	Geographic Information System(s)
GPS	Global Positioning System
MMU	Minimum Mapping Unit
NPS	National Park Service
NS	NatureServe (formally ABI)
NAD	North American Datum (Cartography)
NBII	National Biological Information Infrastructure
NRCS	Natural Resources Conservation Service (formerly Soil Conservation Service)
NVCS	National Vegetation Classification System
PLGR	Precision Light-weight GPS Receiver
RSGIG	Remote Sensing and Geographic Information Group (Bureau of Reclamation)
TNC	The Nature Conservancy
USBR	United States Bureau of Reclamation (Also BOR)
USFS	United States Forest Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator (Cartography)

EXECUTIVE SUMMARY

The Lacreek National Wildlife Refuge (LNWR) was established in 1935 as a waterfowl production area and sanctuary for migratory birds. In accordance with the 1997 National Wildlife Refuge Improvement Act, LNWR's management emphasis shifted toward ecosystem-based management of all resident and migratory species. Refuge and Regional staff asked that a detailed and accurate vegetation map be developed for planning and for managing the Refuge effectively. The Bureau of Reclamation's Remote Sensing and Geographic Information Group (RSGIS) was contracted by US Fish and Wildlife Service to map vegetation and land-use classes at LNWR using remote sensing and GIS technologies originally developed for the National Park Service's Vegetation Mapping Program.

The diverse vegetation and complicated land-use history of Lacreek National Wildlife Refuge presented an unique challenge to mapping vegetation at the plant association level of the US National Vegetation Classification. To meet this challenge, the project consisted of two linked phases: (1) vegetation classification and (2) digital vegetation map production. To classify the vegetation, we sampled representative plots located throughout the 21,950-acre (8884 hectares) project area. Analysis of the plot data using ordination and clustering techniques yielded 27 distinct plant associations. To produce the digital map, we used a combination of new color-infrared aerial photography and fieldwork to interpret the complex patterns of vegetation and land-use at LNWR. Sixty-one land cover units were developed and the 44 vegetation map units matched to the corresponding plant associations. The interpreted map data were converted to a GIS database using ArcInfo©. Draft maps created from the vegetation classification were field-tested and revised before an independent ecologist conducted map accuracy assessment.

Two thousand and sixty-one polygons were delineated, split between the following ecological groups: Nebraska Sandhills, Northern Mixed Grass Prairie, and Great Plains Wetlands. The greatest number of hectares (h) mapped was open water (Pools) with 2150 acres and the largest frequency of polygons mapped belonged to the Peachleaf Willow (*Salix amygdaloides*) Woodland with 164. 386 field data points were used to test the thematic accuracy of the map. Overall thematic map accuracy was 77%.

Products developed for the LNWR Vegetation Mapping Project include

- the final report, vegetation key, map accuracy assessment results and contingency table, and photo interpretation key;
- spatial database coverages of the vegetation map, vegetation plots, accuracy assessment sites, and flight line index;
- digital photos (scanned from 35mm slides) of each vegetation type;
- graphics of all spatial database coverages;
- Federal Geographic Data Committee-compliant metadata for all spatial database coverages and field data.

In addition, the Refuge and USFWS copies of this report contain

- original aerial photographs of the project area;
- digital data files and hard copy data sheets of the observation points, vegetation field plots, and accuracy assessment sites;
- original slides of each vegetation type.

A CD-ROM attached to this report contains text and metadata files, keys, lists, field data, spatial data, the vegetation map, graphics, and ground photos. The USGS will post this project on its website: http://biology.usgs.gov/cbi/bio-char/fws_veg.html. For information on other projects completed by the RSGIS, visit http://www.rsgis.do.usbr.gov/.

1. INTRODUCTION

This report describes the creation of a vegetation classification and a spatial vegetation database for Lacreek National Wildlife Refuge (LNWR) by the Remote Sensing and GIS Group of the Bureau of Reclamation (RSGIS). The objectives of this project were to:

- collect and analyze vegetation data;
- create vegetation and map unit classifications based on the National Vegetation Classification System (NVCS) and Refuge-specific requirements;
- develop a spatial database of LNWR's vegetation, using remote sensing and Geographic Information System (GIS) techniques;
- produce digital and hard copy vegetation maps with a minimum 80% accuracy

1.1 Background

The Prairie-Mountain Region of the USFWS has made a priority of obtaining accurate vegetation data in order to improve Refuge capacity for inventory, planning and management. The USGS-NPS Vegetation Mapping Program (URL: http://biology.usgs.gov/npsveg) was selected as the operating model and LNWR was one of two Refuges chosen to test the applicability of the model. The USGS-NPS Vegetation Mapping Program uses standard methods and protocols to classify, describe, and map vegetation, but they were developed for use at relatively pristine National Parks. At the beginning of this project no one knew how well USGS-NPS methods would work on the modified and manipulated vegetation of a National Wildlife Refuge.

In March 2000, the U. S. Fish and Wildlife Service (USFWS) asked the U.S Bureau of Reclamation's Remote Sensing and Geographic Information Group (RSGIS) to undertake the classification and mapping of vegetation at Lacreek National Wildlife Refuge. The USFWS requested that the U.S. Geological Survey's Biological Resources Division, Center for Biological Informatics (CBI) be responsible for overall project coordination and ensuring that the mapping was performed following standard procedures outlined in the USGS-NPS Vegetation Mapping Program (**Appendix A**). The RSGIS submitted a work proposal (**Appendix B**) to CBI and in June 2000, an Inter-Agency Agreement was established between USFWS, CBI, and RSGIS for this project.

1.2 Scope of Work

The goal of this project was to describe the vegetation of 21,950 acres of the Lacreek National Wildlife Refuge, including adjacent lands owned by other entities. Project goals centered around the following products: digital files of the vegetation map and field data, descriptions of and keys to the plant associations, metadata, map accuracy summaries, and aerial photographs. The RSGIS created most of the products and provided day-to-day project coordination. CBI was responsible for general oversight and adherence to the standards and protocols of the USGS-NPS Vegetation Mapping Program. NatureServe was responsible for producing a preliminary vegetation classification and providing global descriptions for the final plant associations.

1.3 Lacreek National Wildlife Refuge

Lacreek National Wildlife Refuge is located in southwestern South Dakota. To access the Refuge, travel south approximately three miles from Martin, SD (Bennett County) then turn east and go nine miles (**Figure 1**). The Refuge consists of approximately 16,410 acres owned by the USFWS. In addition, portions of this project included state-owned lands managed by the State of South Dakota Department of Game, Fish and Parks and private inholdings (**Figure 2**.).

Climate: The climate of the area is described as semi-arid and is characterized by cold winters and hot summers (USDA 1971). The 42-year average annual precipitation is 17 inches with about 63% of it as rainfall between April and July (URL: http://www.ncdc.noaa.gov/oa/ncdc.html). Annual average temperature is about 60 degrees Fahrenheit and the growing season is generally from mid-May to late September (135 frost-free days). Temperatures range from an average low of 10° F in January to an average high of 89° F in August.

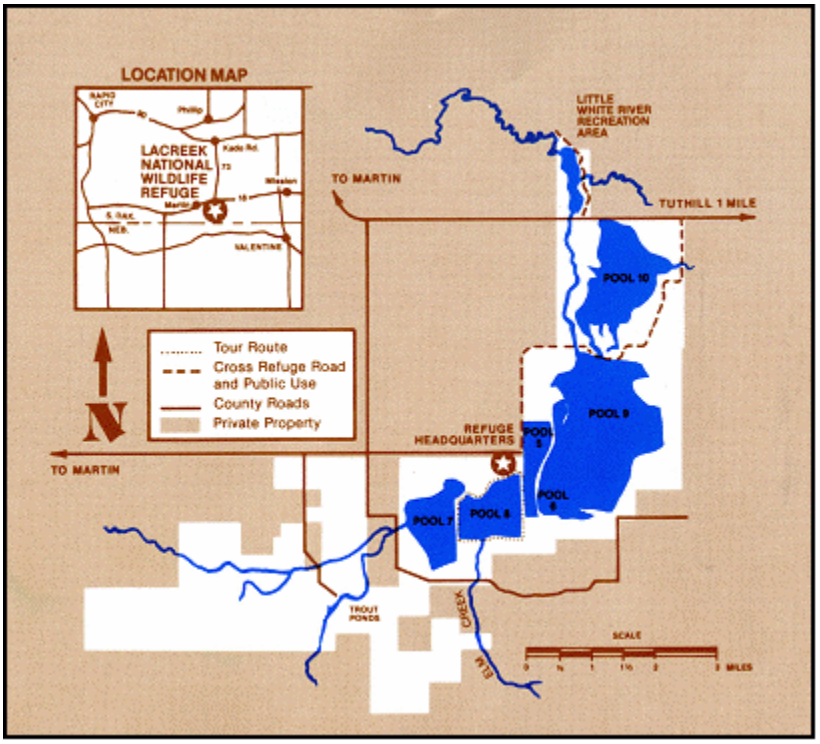

Figure 1. Lacreek National Wildlife Refuge map and location relative to Martin, South Dakota.

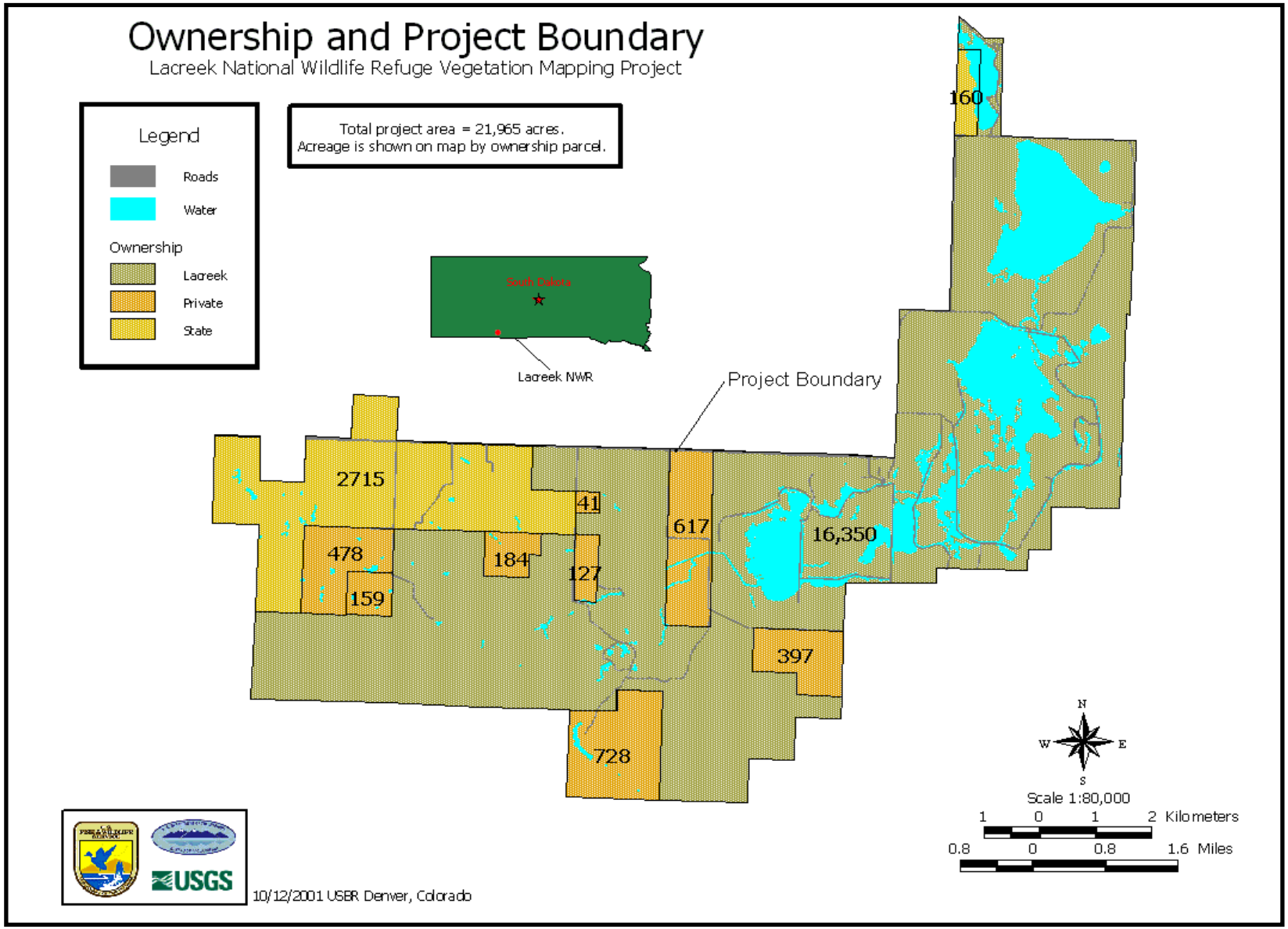

Figure 2. Land ownership and project boundary map for Lacreek National Wildlife Refuge and environs.

Topology: Most of LNWR is located within Lake Creek valley, a broad drainage cut into Valentine and Harrison Formations (Gries 1996). Topography in the valley ranges from nearly level to gently rolling. Soils located near Lake Creek are typically deep, loamy in texture, poorly drained, and occupy sites that have a fluctuating water table. The gently rolling uplands above the valley are characterized by silty loam soils that are well drained. In the southern portion of the Refuge, the topography changes abruptly into rolling dunes that are the northernmost edge of the Nebraska Sandhills. Sandy, well drained to excessively drained soils characterize this portion of the Refuge. Although slopes range from 3 to 35 percent, the original moving dunes are now well stabilized by a cover of grasses and shrubs (USDA 1971).

Wildlife: LNWR supports an array of wildlife species including large numbers of migrating waterfowl and shorebirds. More than 281 species of birds have been recorded since 1959 (URL: http://mountain-prairie.fws.gov/Lacreek/wildlife.htm). Also present on the Refuge are white-tailed and mule deer, burrowing owls, prairie dogs and other animals common to the Central Great Plains region. Fish are present in most of the pools and streams at LNWR. Common species include northern pike, saugeye, large-mouth bass, black crappie, perch, bluegill, pumpkinseed, bullhead, carp and a variety of minnows including the endangered plains topminnow, pearl dace and red-belly dace. Some pools are specifically stocked with rainbow trout (URL: http://mountain-prairie.fws.gov/Lacreek/wildlife.htm).

Vegetation: LNWR is composed of many species common to the northern mixed grass prairie and the sandhill regions of the Great Plains. Western wheatgrass (*Pascopyrum smithii*), green needle grass (*Nassella viridula*), and needle-and-thread grass (*Heterostipa comata*) are typical components of the moderately deep, to deep silty and loamy soils of the gently rolling uplands above Lake Creek. Western wheatgrass is also a common species on the nearly level soils relatively close to the marshes and pools of the Refuge. Almost pure stands of Inland saltgrass (*Distichlis spicata*) are frequently found on saline-alkaline soils that occupy flats and valleys with a fluctuating water table. Several sites have an almost even mixture of both western wheatgrass and inland saltgrass. Prairie cordgrass (*Spartina pectinata*) stands are often found between stands of inland saltgrass/western wheatgrass and cattail (*Typha* spp.). Woodland and shrub communities occur as small, infrequent stands throughout this portion of the Refuge. The most common dominants include peachleaf willow (*Salix amygdaloides*), sandbar willow (*Salix exigua*), and American plum (*Prunus americana*).

The vegetation of the sandhills portion of the Refuge is most diverse and contains the fewest non-native plant species. Prairie sandreed (*Calamovilfa longifolia*), needle-and-thread, sand dropseed (*Sporobolus cryptandrus*), and soapweed (*Yucca glauca*) are the usual dominants. The density of soapweed increases on steeper, north facing slopes. Well-developed stands of needle-and-thread occur on gently rolling to nearly level sites. Stands of switchgrass (*Panicum virgatum*) often occur in relatively small, isolated patches in the concave, lowland areas of the sandhills.

Several non-native/invasive plant species are found within the Refuge. Kentucky bluegrass (*Poa pratensis*), crested wheatgrass (*Agropyron cristatum*) and smooth brome (*Bromus inermis*) are probably the most common species having been planted extensively. Canada thistle (*Cirsium arvense*) is another troublesome exotic species that is being actively controlled in the Refuge by mowing.

Lacreek NWR Scenes: From upper right, Grasslands of the Northern Mixed Grass Prairie, Pelican standing in open water among Central Plains Wetland vegetation, and Rolling grasslands and shrublands of the Nebraska Sandhills Region.

2. MATERIALS AND METHODS

Based on the overall scope and the assigned responsibilities (see 2.1 below), the project was divided into six major steps following the USGS flowchart (**Appendix A**):

1. plan, gather data, and coordinate tasks
2. conduct a field survey of LNWR to understand and sample the vegetation
3. classify the vegetation using field data to USNCV standards and crosswalk it to recognizable map units
4. acquire aerial photography and interpret the photographs using the classification scheme and crosswalk
5. transfer the interpreted data to a digital form
6. ground-truth and assess the accuracy of the final map product.

All protocols for this project as outlined in the following sections can be found in documents produced by The Nature Conservancy (1994a, 1994b, and 1994c) for the USGS-NPS Vegetation Mapping Program and found at its website URL: http://biology.usgs.gov/npsveg.

2.1 Planning, Data Gathering and Coordination

A scoping meeting was held in July 2000 and attended by RSGIS, USFWS (Region 6 and LNWR), NatureServe, and CBI staff. The goals of this meeting were to (1) determine the project boundary, (2) assess the availability of aerial photography, base maps and other data, (3) plan the logistics of doing fieldwork at LNWR, and (4) assign specific tasks to the organizations involved.

The meeting resulted in two guiding decisions:

1. The project extent was defined as the 'executive' boundary of the Refuge plus adjacent state owned land (approximately 21,951 acres).

2. New aerial photography would be required and existing USGS DOQQs (digital orthophoto quarter quadrangles) would be used as basemaps.

Work responsibilities were assigned to the participants:

USBR Responsibilities

- Provide overall project facilitation and coordination.
- Acquire new 1:12,000 scale color infrared aerial photography and obtain necessary USGS DOQQs.
- Verify vegetation and land use/land cover signatures on the aerial photographs.
- Collect data for the vegetation classification and local NVCS descriptions.
- Develop map units linked to the NVCS.
- Provide NatureServe with information regarding the distribution and characteristics of vegetation types within LNWR.
- Interpret and delineate vegetation and land use types using aerial photographs.

- Transfer and automate interpreted photographs to produce a digital spatial database and hard copy vegetation maps.
- Produce spatial coverages of plot and accuracy assessment site locations.
- Provide an analysis of the accuracy assessment.
- Provide a final report describing all aspects of the project.
- Provide a visual guide to the photo signatures of each map unit.
- Document FGDC-compliant metadata for all vegetation data.
- Create a CD-ROM containing the reports, metadata, guides, vegetation classification, plot data, spatial data, vegetation database (map), graphics, and ground photos.

USFWS Responsibilities

- Provide program oversight in conjunction with CBI.
- Supply RSGIS with the LNWR boundary in digital format.

NatureServe Responsibilities

- Develop preliminary list of potential plant associations and provide feedback on the vegetation classification for the study area based on the NVCS, using field data provided by RSGIS.
- Provide guidance to the photo interpreters regarding the ecology and floristic composition of each vegetation type.
- Provide global vegetation descriptions and assist with keys to the vegetation.

RSGIS obtained copies of maps, soil surveys, reports, and other documents describing the Refuge and its environmental setting. LNWR provided species lists, annual reports, and their draft comprehensive conservation plan. The Region 6 office of the USFWS provided a digital copy of the project area boundary

2.2 Field Survey

RSGIS conducted a field survey in September 2000 and August 2001, during which both observation point data and plot data were collected. Observation points allowed the field person to become generally familiar with the vegetation while field checking NatureServe's list of potential plant associations. Data collected at each observation point included a general description of the vegetation, UTM coordinates, estimates of foliar cover for the dominant species, and a brief description of the environmental characteristics (**Appendix C**). We collected data at 167 observation points during the September field survey (**Figure 3**).

We also sampled 65 vegetation plots during the August 2000 field survey (**Figure 4**). These plots differed from the observation points in two important ways. First, plot boundaries were formally defined, and second, the data we collected were quantitative and much more detailed. The plots were placed subjectively in vegetation that was judged to be "representative" and relatively homogeneous over at least 0.5 ha (the size of the minimum mapping unit). Ecotones were not sampled, and smaller areas were

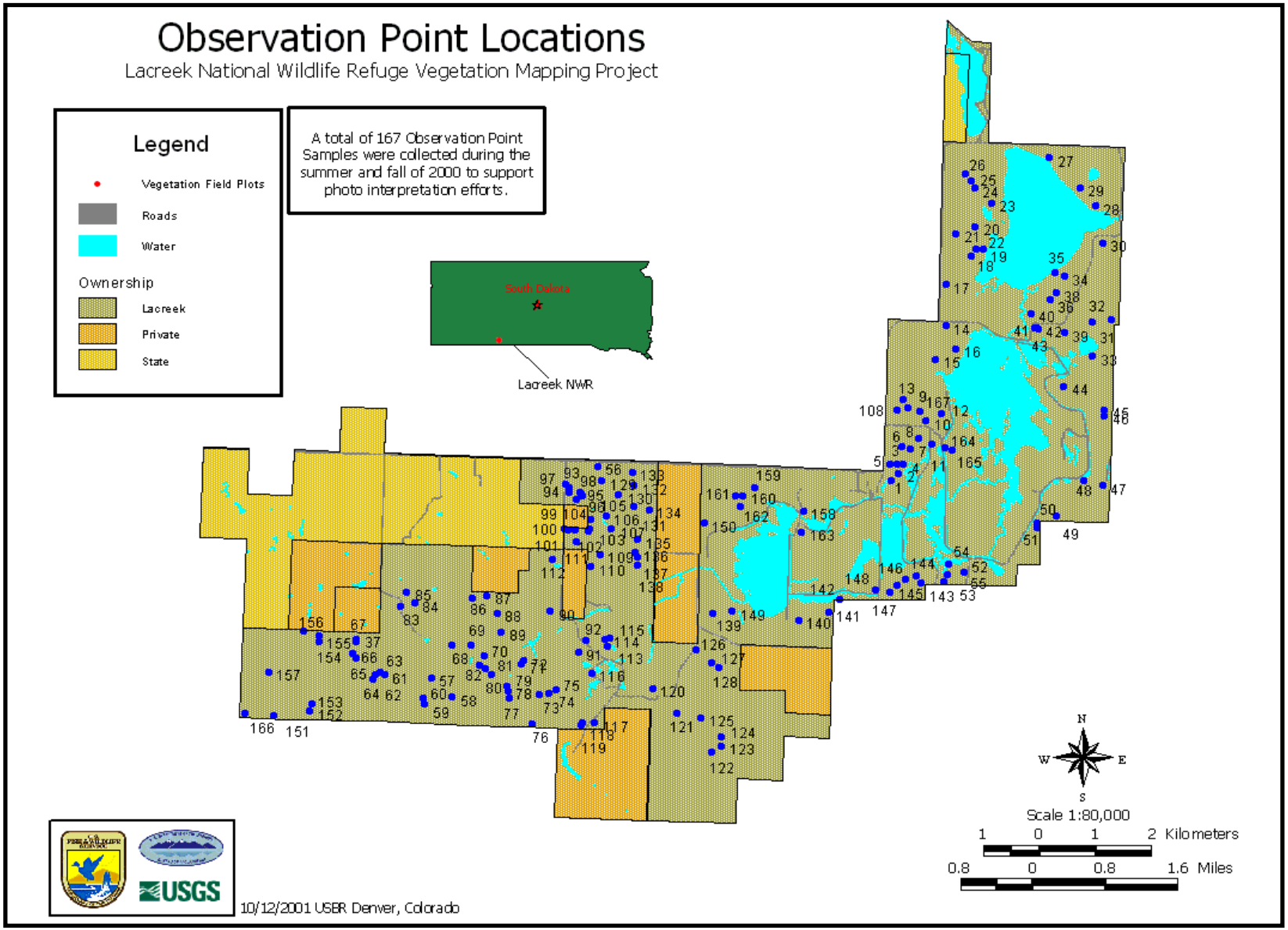

Figure 3. Location of observation points at Lacreek National Wildlife Refuge.

only sampled if they represented unique or distinctive vegetation types. We used 20 x 20 m square plots to sample forest and woodland communities, while shrubland and herbaceous communities were sampled using 10 x 10 m plots. We made an effort to sample three plots per vegetation type with more plots in types not previously documented by the NVCS. The plots were spread across the Refuge to capture the full range of variation.

The descriptive information we collected in each plot included slope, aspect, elevation, soil characteristics, and evidence of wildlife and human disturbance (**Appendix C**). To characterize the vegetation in a plot, we estimated the cover of all vascular plant species (Daubenmire 1959) by layer (herb, shrub, tall shrub, subcanopy, canopy, etc.). The UTM coordinates and elevation of all plots were logged using a Garmin™ 12XL GPS receiver. We took photographs (35 mm format) of each plot and scanned them as digital images. Scanned representative slides for all plots are included in **Appendix G** and all scanned images can be found on the CD_ROM attached to this report. Data collected for each plot was entered into a MS Acess© database and analyzed by NatureServe ecologists using the procedures described in **Section 2.3**.

2.3 NVCS Classification at Lacreek NWR

The National Vegetation Classification System (NVCS) for the United States was selected as the vegetation classification standard for this project for several reasons. First, the NVCS is the system mandated by the USGS-NPS Vegetation Mapping Program. Second, the Federal Geographic Data Committee (FGDC) (FGDC, 1997) has adopted the NVCS to the formation level as a standard for federal agencies. Finally, a national (as opposed to regional, state, or local) vegetation classification system facilitates resource stewardship by ensuring that the same plant associations get the same names throughout the National Refuge System. In short, the strengths of the NVCS include:

- it is vegetation based
- uses a systematic approach to classify a continuum
- emphasizes natural and existing vegetation
- uses a combined physiognomic-floristic hierarchy
- identifies vegetation units based on both qualitative and quantitative data
- is appropriate for mapping at multiple scales

The NVCS was established primarily by The Nature Conservancy (TNC) and is being implemented and updated by NatureServe in support of the network of Natural Heritage Programs (Grossman *et al.* 1998). Development and refinement of the classification is an ongoing process, and proposed revisions are reviewed both locally and nationally. TNC published two volumes describing the classification of U.S. vegetation as of April 1997 (Grossman *et al.* 1998). This publication can be found on the Internet (URL: http://www.natureserve.org/publications/library.jsp#nspubs) NatureServe also posts regular updates to the list of plant associations in the United States and Canada on their online database server: http://www.natureserve.org/explorer).

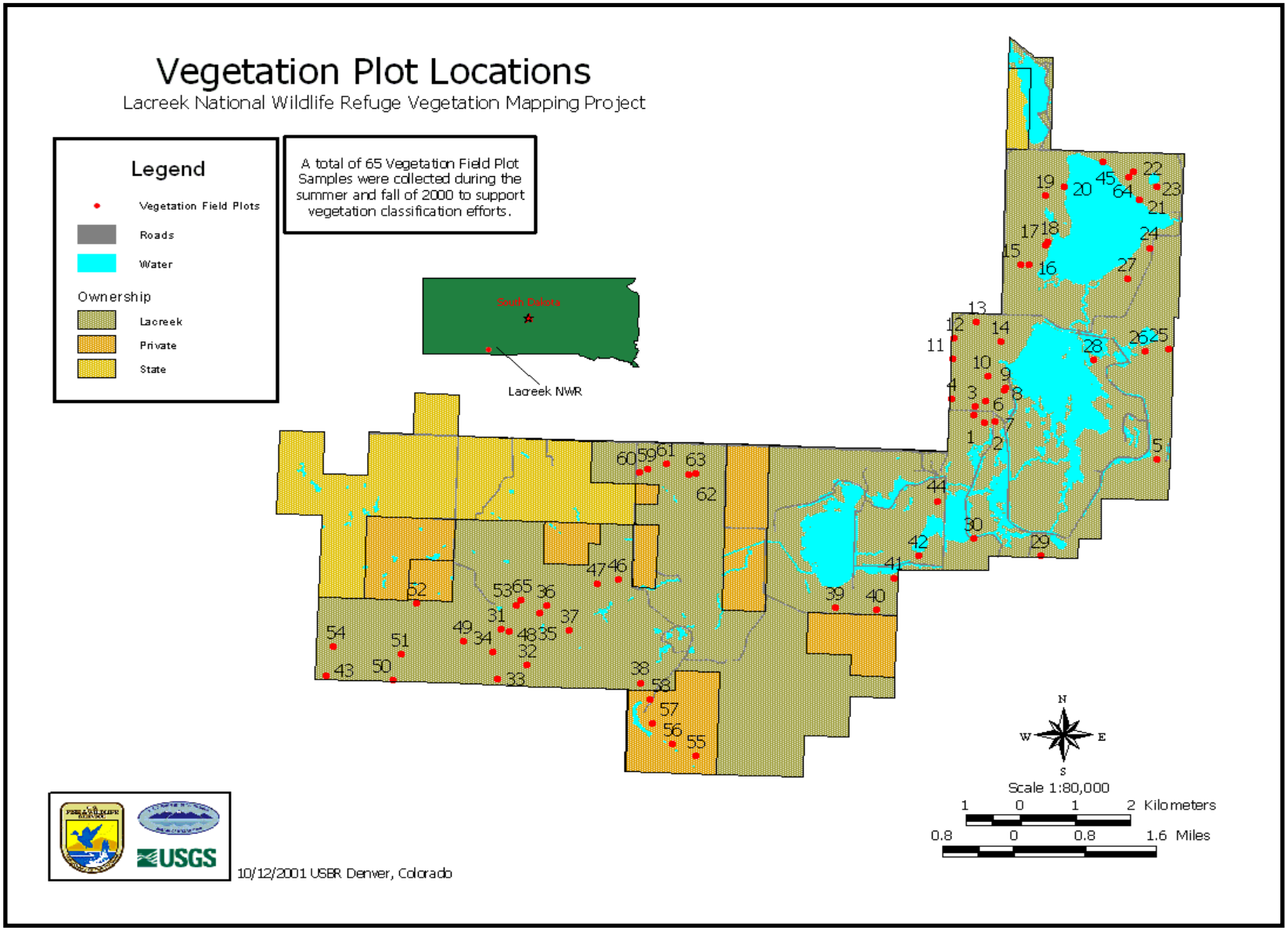

Figure 4. Location of vegetation plots at Lacreek National Wildlife Refuge.

The procedure for classifying vegetation followed guidelines described in the Vegetation Classification Standard (FGDC 1997), which was derived from the NVCS. The NVCS is a species-based, hierarchical system with seven levels (Grossman *et al.* 1998). The highest (*i.e.* course) levels of the hierarchy have a broad geographic perspective and use physiognomic features to distinguish among groups of plant communities. The lower levels *(i.e*. finest) have a local and site-specific perspective and are based on floristics (**Table 1**). The two lowest levels (alliance and association) were used in the LNWR project.

Table 1. An example of the NVCS physiognomic-floristic classification hierarchy.

Level	Primary Basis For Classification	Example
Class	Growth form and structure of vegetation	Woodland
Subclass	Growth form characteristics, e.g., leaf phenology	Deciduous Woodland
Group	Leaf types, corresponding to climate	Cold-deciduous Woodland
Subgroup	Relative human impact (natural/semi-natural or cultural)	Natural/Semi-natural
Formation	Additional physiognomic and environmental factors, including hydrology	Temporarily Flooded Cold-deciduous Woodland
Alliance	Dominant/diagnostic species of uppermost or dominant stratum	*Salix amygdaloides* Temporarily Flooded Woodland Alliance
Association	Additional dominant/diagnostic species from any stratum	*Salix amygdaloides/Salix exigua* Woodland

The association is defined as "a plant community of definite floristic composition, uniform habitat conditions, and uniform physiognomy" (see Flahault and Schroter 1910 in Moravec 1993). Associations are separated from alliances through the use of total floristic composition and are named by the most dominant and/or indicator species. If two or more dominant species occur in the same stratum a dash symbol is used between the names. If the species occur in different strata then a slash is used. Parentheses indicate that a diagnostic species is not always present. Alliances are physiognomically uniform groups of plant associations that share dominant or diagnostic species, usually found in the uppermost stratum of the vegetation. For forested types, the alliance is roughly equivalent to the "cover type" of the Society of American Foresters. Alliances also include non-forested types.

Unlike classifications based on habitat types or potential vegetation, the NVCS strives to describe existing vegetation, whether natural or cultural vegetation. However, due in part to the conservation focus of TNC and NatureServe, the classification of natural vegetation types is often better developed than that of cultural or modified types. The NVCS is also unique in that the association is the basic unit, with the higher levels of the hierarchy representing aggregations of units in the lower levels. This differs from other types that work from the top down.

Preparing the Data for Analysis

The vegetation classification for LNWR began with RSGIS and NatureServe ecologists manually sorting observation point and plot data into groups based on vegetation structure and composition. Most of the plots could be evaluated qualitatively and assigned to an existing NVCS alliance or association. In a few instances, new NVCS units were defined from quantitative analysis of the plot data using ordination techniques described below. The results of the numerical analyses were compared to the subjective classification so that discrepancies between the two could be reconciled.

Data from the 65 vegetation plots sampled at LNWR were entered into a MS Acess© database using TNC's PLOTS interface and following procedures outlined by the NVCS (Grossman *et al.* 1998). The cover values for the species in each plot were used to create a plots-by-species data matrix. Prior to analysis, all species with total cover values (summed over all plots) of 1% or less were removed from the data matrix. This prevented minor species from controlling the classification. The resulting matrix was then run through a number of computer analyses designed to organize and summarize the compositional and structural characteristics of the vegetation and assess patterns related to environmental gradients.

Data Analysis

Following procedures described by Grossman *et al.* (1998) and McCune and Mefford (1999), the plots were analyzed using TWINSPAN (a classification program) and DECORANA (an ordination program). The TWINSPAN grouping analyses were conducted using relative cover values, while raw cover values were used in the DECORANA ordination procedures. TWINSPAN recognizes distinct ecological groups of plots such as wetlands, riparian woodlands, shrublands, and grasslands. DECORANA clarifies the patterns revealed by the classification and places the plots along a two-dimensional environmental gradient.

In most cases, there were only a few sample plots per vegetation type; so the numerical analyses (as described above) were compared to the subjective classification so that any discrepancies between the two could be detected. Almost all of the numerical classes matched existing NVCS types described for the Midwest portion of the U.S. (Faber-Langendoen, D. *et al.* 1996). Those that didn't were sent to NatureServe for consideration as new NVCS plant associations.

A preliminary classification of the LNWR was the end product of this process. RSGIS ecologists, photo interpreters, and Refuge staff field-reviewed the classification. RSGIS and NatureServe prepared a dichotomous map unit key for LNWR (**Appendix D**). The key was tested during the accuracy assessment process. An illustrated guide to the map units **(Appendix G)** was also developed to assist managers and field researchers in identifying plant associations in the field.

2.4 Aerial Photograph Acquisition and Photo-interpretation

Horizons, Inc. (Rapid City, SD) flew color-infrared (CIR) aerial photography for LNWR at 1:12,000-scale on July 27, 2000. We chose CIR film because of its ability to highlight subtle differences in vegetation, especially among wetland types. Frame overlap on the 1:12,000-scale photographs was between 50% and 60% along the flight lines and 20% to 30% between the flight lines (**Figure 5**). RSGIS photo interpreters used 9" X 9" prints of the 1:12,000-scale photography (**Figure 6**) to map the Refuge's vegetation A total of nine digital orthophoto quarter quadrangle basemaps were obtained from the USGS and mosaiced to produce the project's basemap (**Title Page)**

RSGIS interpreted the aerial photographs twice. The first interpretation identified patches of homogenous vegetation (areas on the photos with similar tone, texture, color and landscape position) to identify the best sites to place sample plots. The final interpretation was further refined using NVCS-derived map units, field notes, observation point and vegetation plot data to prepare the GIS vegetation database.

Stereoscopic photo interpretation

For both levels of interpretation, we covered each 9"x 9" aerial photograph with sheets of translucent (semi-frosted) Mylar. The aerial photos and their overlays were backlit on a light table and a stereoscope was used to help recognize photo signatures and three-dimensional features. Corner and side tics, photograph and flight line numbers were marked on each Mylar sheet. Polygons were delineated using a 0.5 mm lead pencil. Only the center portion of each aerial photograph was interpreted to minimize the effects of edge distortion. In order to insure completeness and accuracy, digital transfer specialists reviewed all of the interpreted photos for consistency and recommended changes where necessary.

The map units delineated on the photos were derived from the NVCS classification as constrained by the limitations of the photography. Photo interpreters applied the preliminary NVCS classification to aerial photo signatures to see how many plant associations could be recognized on the photos. In most instances, one NVCS association corresponded to one map unit. However, sometimes a plant association could not be recognized consistently on the photos or the photo interpreter could see more detail than was recognized by the vegetation classification. These problems were overcome by using two separate but related classifications: (1) a NVCS classification for the plot data and (2) a map unit classification for the GIS database. The two were related or "crosswalked" by noting where plant associations were lumped into single map units and where other associations were split into multiple map units.

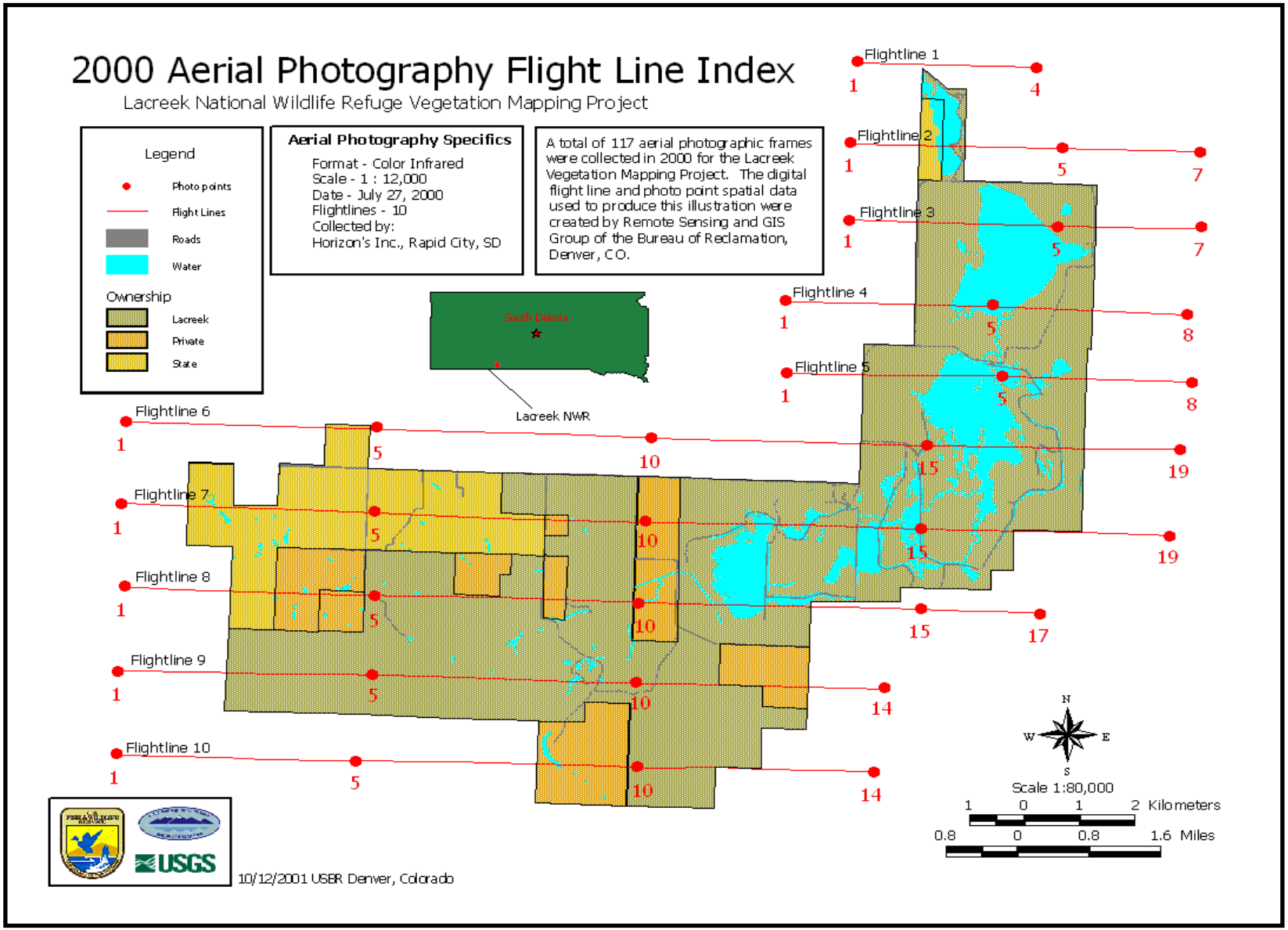

Figure 5. 2000 aerial photo flight line index map for Lacreek National Wildlife Refuge.

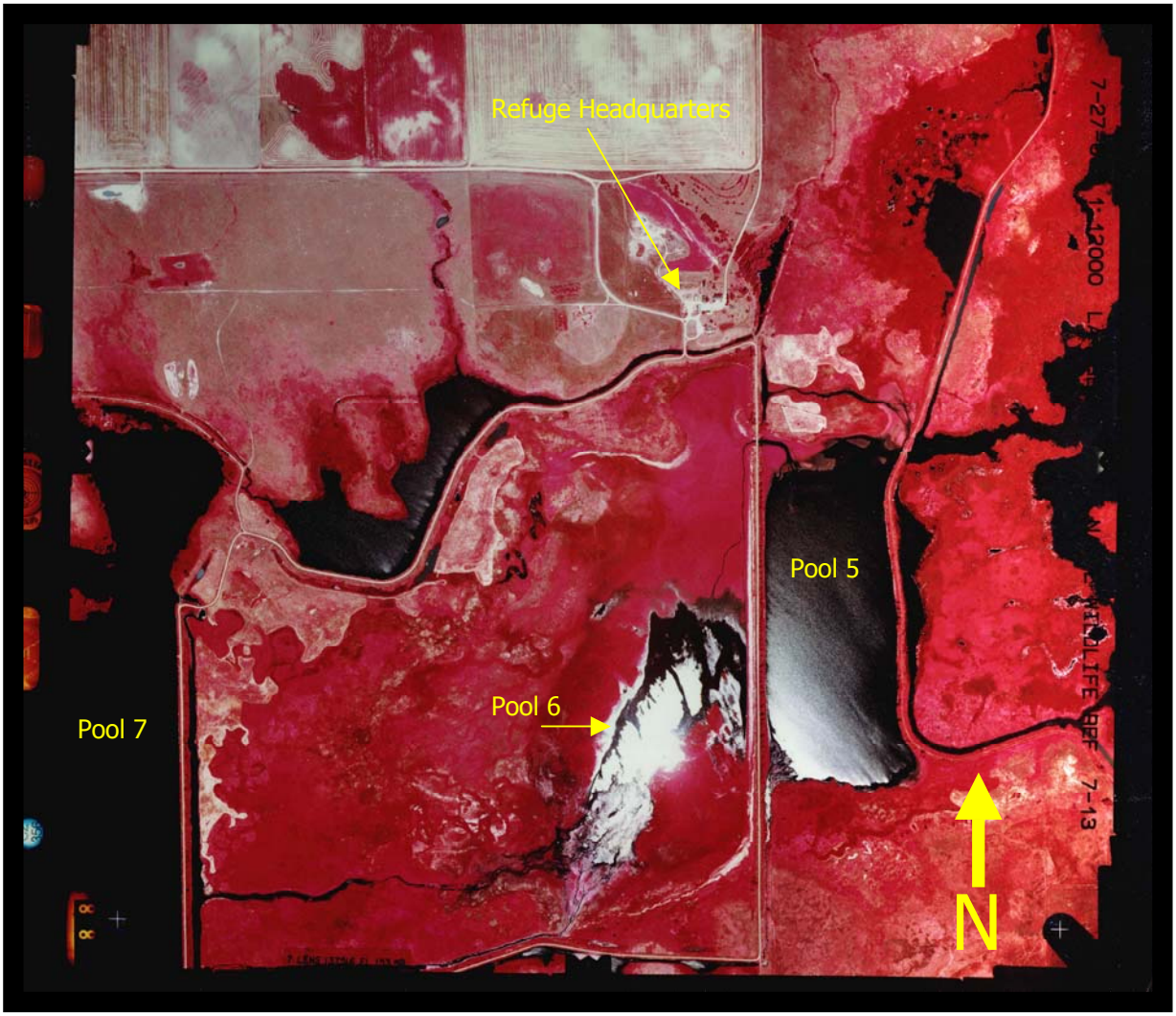

Figure 6. Example of an aerial photograph for the Lacreek National Wildlife Refuge Vegetation Mapping Project (example is not to scale).

We created map units for land-use types based on the system developed by Anderson (1976) to classify remotely sensed cover types. This includes unvegetated lands not included in the NVCS, such as roads, facilities, and agricultural fields. A third class of map units was defined especially for LNWR to cover vegetation types that were easily mapped but were not included in either the NVCS or Anderson, such as priaire dog towns. In addition to refuge special types, LNWR staff also specified other mapping criteria based on management needs. These were addressed by creating a set of modifiers (*i.e.* new polygon attribute items) that provided information on the physiognomic structure of the vegetation.

A list of the final map units appears in **Table 3**.

2.5 Digital Transfer of Photo Interpreted Data

The transfer process removes much of an aerial photograph's inherent distortion and ties the interpreted data to real-world coordinates so it can be digitally automated. To accomplish this for LNWR, an ArcInfo© GIS database was created using in-house protocols. The protocols consist of a shell (*i.e.* master file) of Arc Macro Language (AML) scripts and menus (nearly 100 files) that automate the transfer process, thus insuring that all spatial and attribute data are consistent and stored properly (**Figure 7**). The actual transfer of information from the interpreted aerial photographs to a digital, geo-referenced format involves two basic techniques: (1) scanning the interpreted line work and (2) on-screen digitizing. Both techniques require a background image or basemap. For LNWR, we used nine black/white digital orthophoto quarter quadrangles (**Figure 8**).

The scanning technique used for LNWR involved a multi-step process whereby the Mylar overlay sheets produced by the photo interpreters were scanned into a digital form. The digital image file (tagged image format =.tif) created from the scanned sheet was then converted from a raster image to a vector file using RSGIS-developed AMLs in ArcInfo©. The vector file or 'line coverage' was then geo-referenced to the orthophoto base map. The essential principle of geo-referencing is to match the scale and position of features on the photographs with the scale and position of the same features on the orthophotos. Technicians accomplished this by adjusting the scale of the scanned Mylar between known control points using computer program routines until the adjustment was considered a good fit.

Large Format Scanning

Any remaining land use classes not already scanned (such as roads) were transferred by means of on-screen digitizing. This process entered data into GIS format by manually tracing digital lines (using a mouse) on a computer monitor screen with a DOQQ as a background image. The completed line work for each photo was then edge matched. Finally, polygon topology was built and attribute information added to produce digital vector or polygon coverages (one per photo) that were combined into a final coverage for the entire Refuge.

On-screen Digitizing

We attributed, or labeled, each vegetation polygon for LNWR with necessary information pertaining to map units, NVCS units, Anderson land-use classes, Refuge-special units, and other relevant data. The attribute items are listed in **Table 2** and are referenced in the LNWR vegetation look-up table included on the accompanying CD-ROM. Attribute items include standard GIS categories (area, perimeter), NVCS types mandated by the program (Association, Alliance), and USFWS specific modifiers (mod and eco).

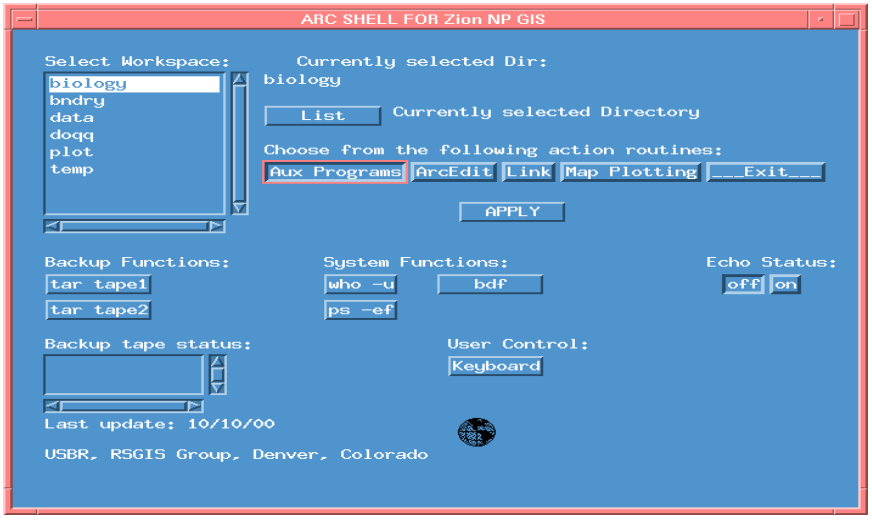

Figure 7. Example of UNIX ArcInfo© Shell Menu Interface.

Table 2. Lacreek Vegetation Spatial Database (GIS Coverage) polygon attribute items and descriptions.

AREA* Surface area of the polygon in meters squared
PERIMETER* Perimeter of the polygon in meters
LNWREEK_VEG#* Unique internal polygon coding
LNWREEK_VEG-ID* Unique internal polygon coding
VEG_CODE Map unit code -project derived, project specific
VEG_NAME Map unit description name - project derived, project specific
ECO Ecological description
PHYS Physiographic description
MOD "R" Modifier indicating the polygon contains an additional USFWS_NAME
FWS_NAME Management unit name – USFWS derived, project specific, not NVCS
FWS_CODE Management unit code – USFWS derived, project specific, not NVCS
ASSN_NAME Project global community name - NVCS association
ASSN_CNAME Project global common community name -
SYNONYM Other common name of association
ASSN_CEGL Community element global code - TNC elcode link to NVCS association
ALL_NAME NVCS alliance name
ALL_CNAME Common alliance name - translated common name of NVCS alliance
NVCS_CODE NVCS code - to NVCS formation level
CLASS NVCS formation class - class name (code)
SUBCLASS NVCS formation subclass - subclass name (code)
GROUP NVCS formation group - group name (code)
SUBGROUP NVCS formation subgroup - subgroup name (code)
FORMATION NVCS formation - formation name
LUC_II Land use and land cover classification system (USGS, Anderson et al. 1976)
COMMENT1 General description of the map unit
COMMENT2 General comment of how the map unit relates to other map units.
LOCATION Location of the polygon, either on LNWR ("Refuge") or on State of South Dakota Lands ("State")
PDOG Evidence of prairie dog activity in the polygon
(*ArcInfo default items)
ACRES Surface Area of Polygon in Acres (calculated: 0.000247 x **Area**)

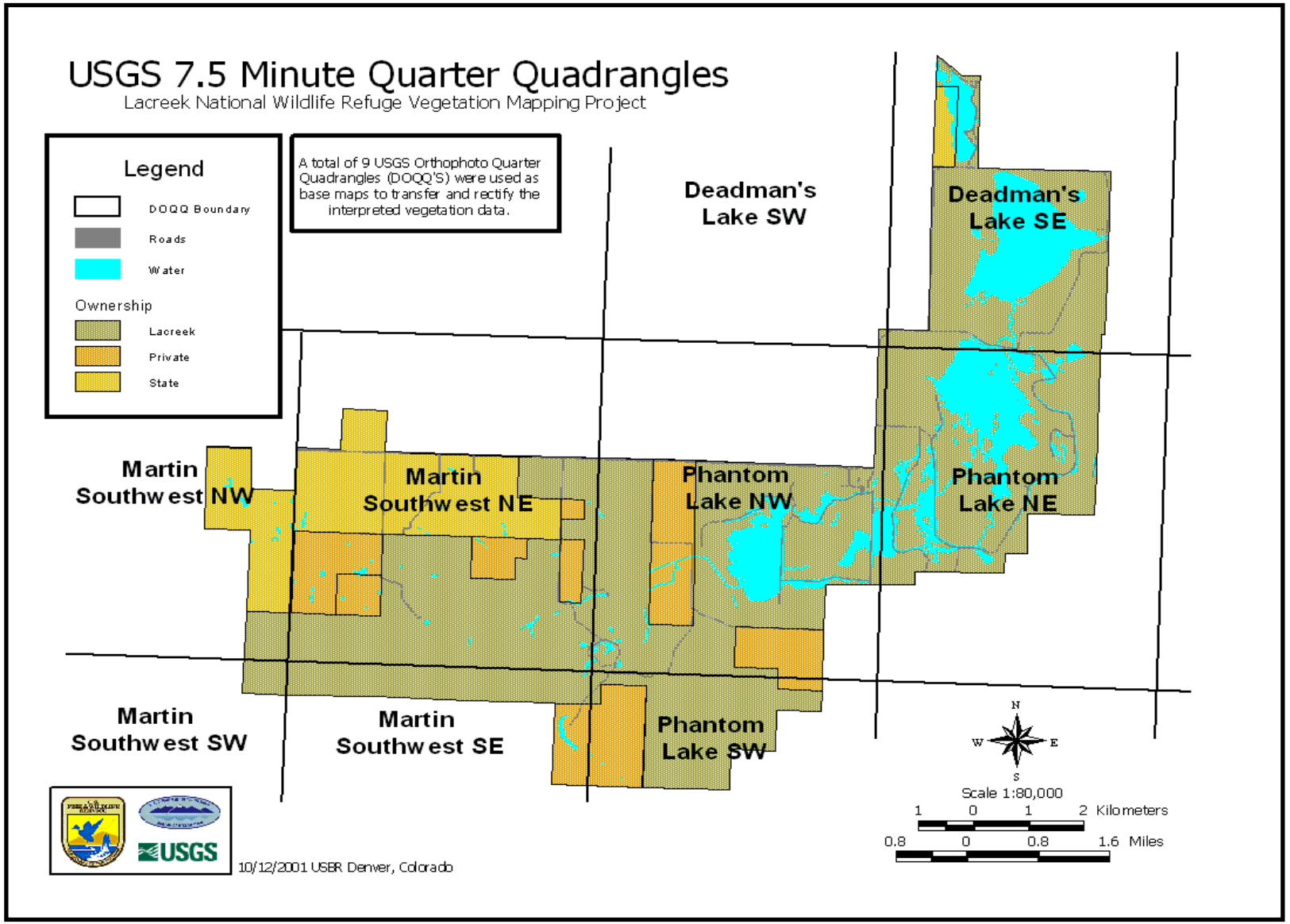

Figure 8. 7.5 minute digital orthophoto quarter quadrangle (DOQQ) index map for Lacreek National Wildlife Refuge.

2.6 Field Verification and Accuracy Assessment

Once the aerial photo interpretation transfer and digitization was complete, we printed draft 1:12,000-scale hard copy vegetation maps. Photo interpreters checked the map against the interpreted aerial photographs to ensure that the polygons were labeled properly and to locate any extra or missing lines. They also compared the map labels to the observation and plot data. Copies of the revised draft map were then sent to the Refuge for review and taken into field by the photo interpreters for ground-truthing. During the ground-truthing process, we collected additional plot data, observation points, and verified aerial photograph signatures using landmarks and GPS waypoints. The map and map units were then modified to correct any mistakes.

RSGIS conducted an assessment of the vegetation map's thematic accuracy in the summer of 2001. Accuracy assessment (AA) sample sites were selected by following the protocols defined by the USGS-NPS Vegetation Mapping Program (TNC 1994a). AA points were selected using a 100-meter grid overlain on the LNWR vegetation coverage in ArcInfo©. The origin of the grid was selected using a random number table and the intersections of the gridlines became the pool of potential sample points. Sample points were removed from the pool if they fell within 10 meters of a vegetation polygon line, fell on a non-vegetated site, or fell on a less than 0.5 ha polygon (mmu). The remaining points were attributed by vegetation type. Between five and 30 points were randomly selected for each vegetation type using a random number generator in ArcInfo©. More AA sample points were selected for common map units and fewer selected for rare map units. Some extremely rare map units had fewer than five AA sample points due to their small size and limited distribution. A total 386 points were selected for accuracy assessment purposes (**Figure 9**).

AA logistics involved plotting AA points and polygon boundaries on hard copy 1:12,000-scale topographic quadrangle maps. Each point's UTM coordinates were uploaded into a Garmin GPS unit to help find the field location of the AA points. Armed with the vegetation key, the digital AA point coordinates, and the map, an RSGIS ecologist (who had no involvement with the project otherwise) collected AA data at LNWR. The ecologist walked to each AA point and used the vegetation key (**Appendix D**) to identify the plant association within a 40m radius. Data recorded for each point included the community name(s), dominant species, environmental conditions, and rationale for the identification (**Appendix C**).

Upon completion of the fieldwork, AA data were entered into a MS Acess© database and reviewed for entry errors. Incomplete data on the field sheets, including missing GPS coordinates, were corrected if possible. Final AA points were viewed in ArcView in relation to the vegetation map coverage. Actual assessment consisted of comparing the determination made in the field for each AA point to the polygon map label. These comparisons were made at an AA meeting held in September 2001 by a panel of USFWS and BOR staff. Each point was reviewed for accuracy and for errors made by the AA ecologist. In this manner, "false" errors or mismatches between a polygon and

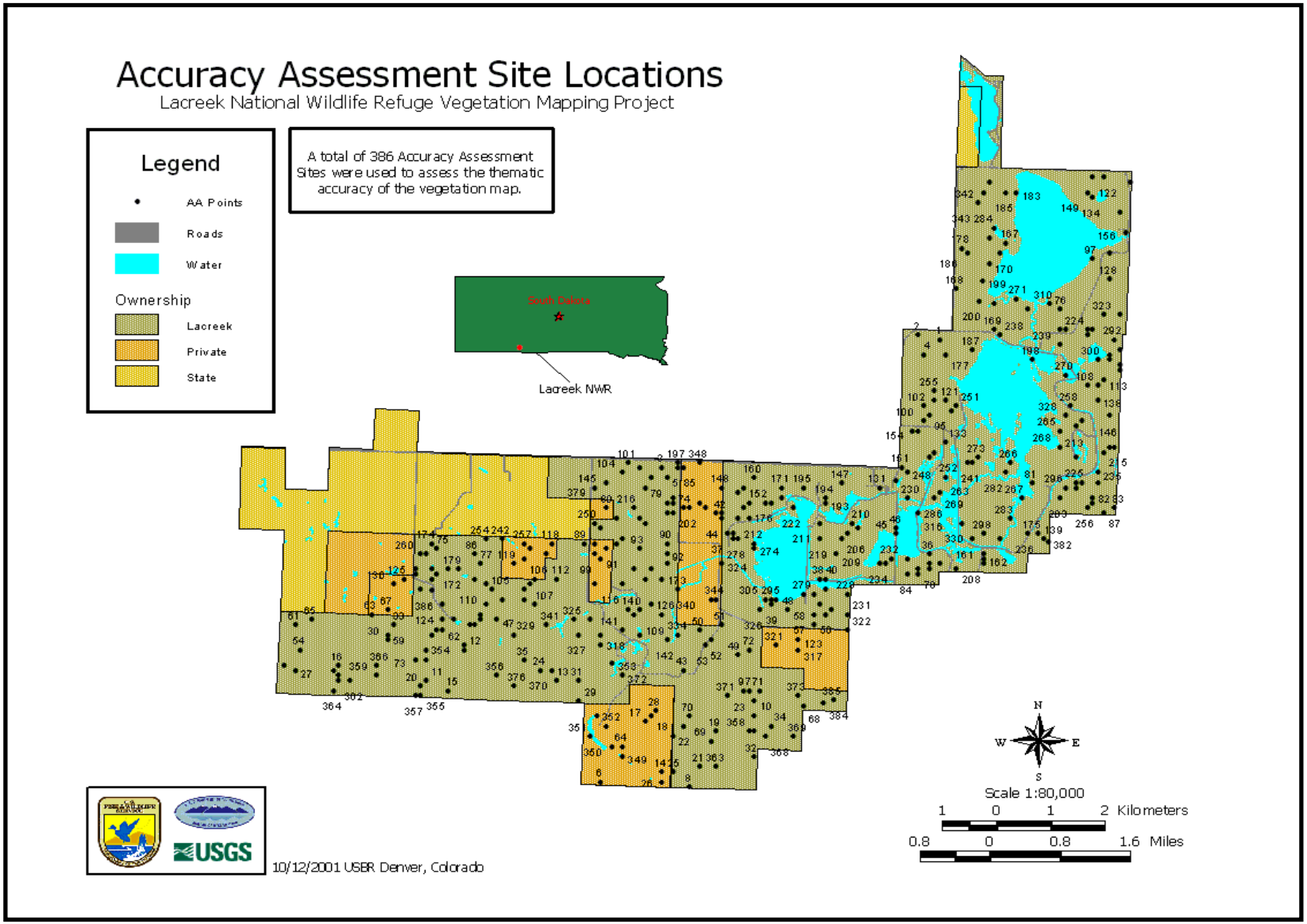

Figure 9. Locations of accuracy assessment points at Lacreek National Wildlife Refuge.

an accuracy assessment were separated from true errors. False errors were generally recognized as resulting from one of three problems:

- **GPS errors:** The point was located incorrectly (wrong polygon) due to GPS limitations (+/- error). Usually the point was too close to a polygon boundary. (10 meter buffer was not sufficient)
- **Ecotone errors:** A point occurred in a zone of transition between two types.
- **Intuitive errors:** A point was classified differently than the polygon label but was overruled by USFWS staff. These errors probably resulted either from assessing areas too small to map (*i.e.* inclusion) or assessing too small an area around the point while on the ground. Also, seasonality changes in species composition (*e.g.* warm season and cool season grasses) from the time of the photography to the time of the AA were addressed.

An assessment for each point was recorded in error matrix (*i.e.* contingency table) upon final approval by the LNWR staff.

Landuse contrast at Lacreek National Wildlife Refuge highlighting the differences in herbaceous cover on grazed (left) and ungrazed (right) in Soapweed Yucca Shrubland.

3. RESULTS AND DISCUSSION

3.1 NVCS Classification at Lacreek NWR

Visual inspection, classification and ordination of the 65 plots sampled at LNWR resulted in 23 plant associations (see **Table 3**). We determined the classification using species foliar cover values following procedures described by Grossman *et al.* (1988) and McCune and Mefford (1999). The plot data was analyzed several times using TWINSPAN (classification technique) and DECORANA (ordination technique) (**Figures 10-11**). We edited the plot data prior to analysis by first removing all species that had total cover values (summed over all 65 plots) of $\leq$ 1%. Further, all TWINSPAN grouping analyses were conducted using relative foliar cover values, while raw foliar cover scores were used in the DECORANA ordination procedures. The data was then subjectively evaluated for plots that demonstrated exceptionally low similarity to the remaining plots, *i.e*. outliers (Gauch 1982).

Prairie dog town plots were the first outlier group to be identified and removed from the data set due to their extremely heterogeneous composition. We then combined the remaining plots that demonstrated considerable similarity into composite plots. By using DECORANA ordination again we identified the composite class of *Polygonum amphibum* Herbaceous Vegetation and the *Juncus balticus* Herbaceous Vegetation as a second outlier and removed it prior to the final ordination. Removing the outliers from the analysis spread the remaining plots across a larger two-dimensional space helping to emphasize environmental gradients and highlighting distinct communities.

The results of the classification process produced several large and predictable groups such as wetlands, mesic grasslands, sandhills grasslands and shrublands, and "Restoration Areas". Segregation of these types appeared to be based on a complex environmental gradient related to soil type/texture, land-use history, and soil moisture levels. Sandhills communities dominated by *Hesperostipa comata and Yucca glauca* were ordinated at one end of the resulting gradient while wetland associations dominated by *Salix* sp. and *Typha* sp. were found at the opposite end. The middle had an intricate mixture of natural grasslands, introduced grasslands, and restoration areas.

Based on the resulting classification, we separated the vegetation of LNWR into three broad physiognomic categories. These categories are similar to ecological groups in that they share similar ecological processes. The use of ecological groups is a way of emphasizing some of the ecological, rather than floristic or physiognomic, similarities among the types. The three types found at LNWR include the Nebraska Sandhills, Northern Mixed Grass Prairie, and Great Plains Wetlands. Most of the plant associations matched the preliminary classification and were similar for other classified sites in the Great Plains and described in the Midwest Classification (Faber-Langendoen *et al.* 1996 (**Table 3**). The final NVCS classification summary and detailed NVCS descriptions are included in **(Appendix E)**.

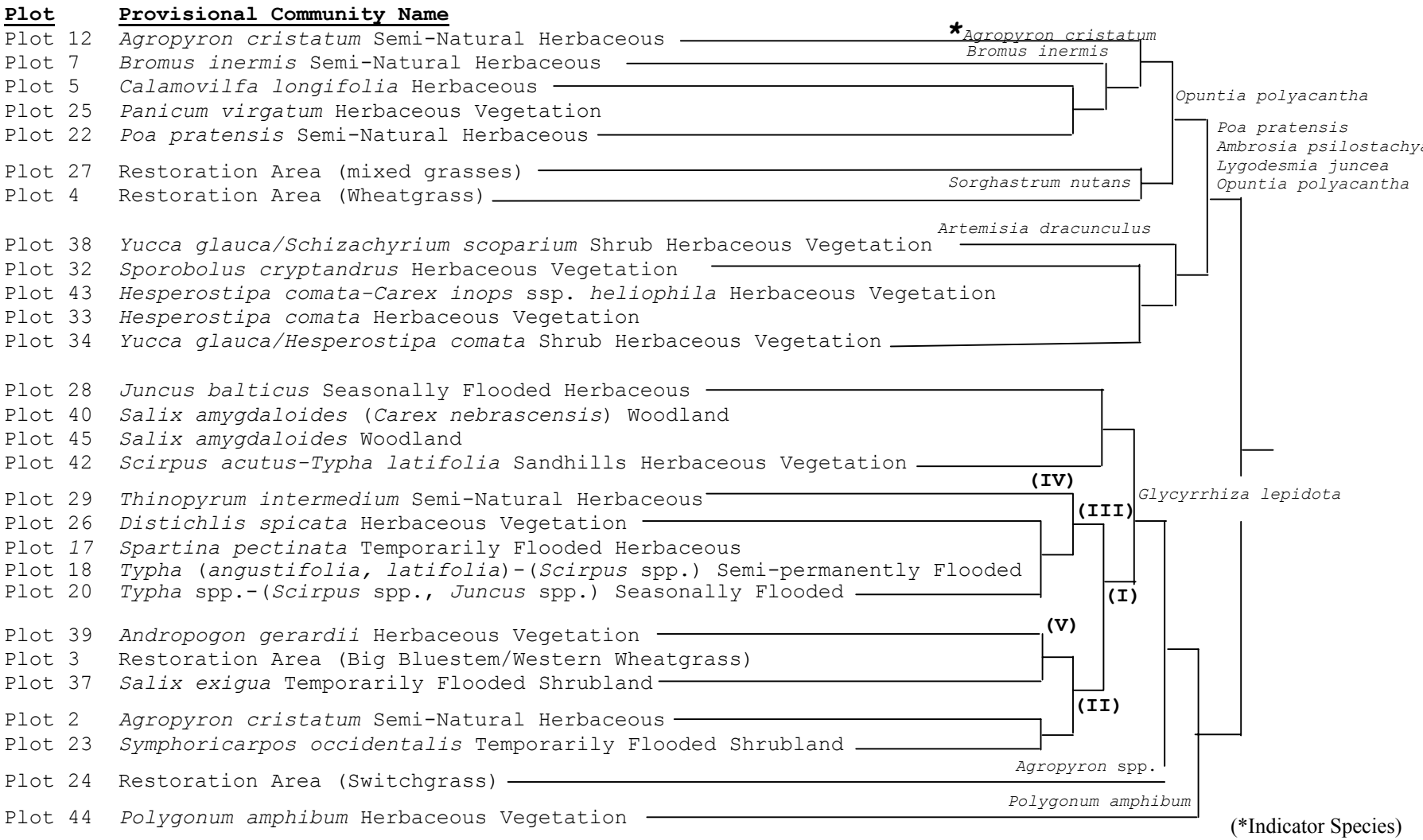

Figure 10. Final twinspan dendrogram of 28 plots (composite plots and individual plots) collected at Lacreek National Wildlife Refuge.

- Indicator species: (I) = *Cirsium arvense*, *Aster ericoides*, and *Sonchus arvensis*, (II) = *Bromus inermis*, (III) = *Sonchus arvensis*, (IV) = *Thinopyrum intermedium*, and (V) = *Andropogon gerardii*.

Figure 11. Detrended correspondence analysis ordination of 24 vegetation plots (composite plots and individual plots) recorded during the 2000 field season from Lacreek National Wildlife Refuge, Martin, South Dakota.

-please see Figure 10 for provisional community names for each plot.

Table 3. Vegetation communities (plant associations) recognized at Lacreek NWR and environs based on the NVCS.

Community Name (Association)	Common Name (Synonym)	Elcode*
Northern Mixed Grass Prairie: Animal Units		
Blacktailed Prairie Dog Town Grassland Complex	Blacktailed Prairie Dog Town Grassland Complex,	CECX002003
Sandhills Vegetation		
Calamovilfa longifolia - Carex inops ssp. heliophila Herbaceous Vegetation.	Prairie Sandreed - Sun Sedge Herbaceous Vegetation	CEGL001471
Calamovilfa longifolia - Hesperostipa comata Herbaceous Vegetation	Prairie Sandreed - Needle-and-Thread Herbaceous Vegetation	CEGL001473
Schizachyrium scoparium - Bouteloua (curtipendula, gracilis) - Carex filifolia Herbaceous Vegetation	Little Bluestem - (Sideoats Grama, Blue Grama) - Threadleaf Sedge Herbaceous Vegetation	CEGL001681
Yucca glauca / Calamovilfa longifolia Shrub Herbaceous Vegetation	Soapweed Yucca / Prairie Sandreed Shrub Herbaceous Vegetation	CEGL002675
Northern Mixed Grass Prairie: Upland Grasslands		
Agropyron cristatum - (Pascopyrum smithii, Hesperostipa comata) Semi-natural Herbaceous Vegetation	Crested Wheatgrass - (Western Wheatgrass, Needle-and-Thread) Semi-natural Herbaceous Vegetation	CEGL005266
Andropogon gerardii - Panicum virgatum - Helianthus grosseserratus Herbaceous Vegetation	Big Bluestem - Switchgrass - Sawtooth Sunflower Herbaceous Vegetation	CEGL002024
Bromus inermis - (Pascopyrum smithii) Semi-natural Herbaceous Vegetation	Smooth Brome - (Western Wheatgrass) Semi-natural Herbaceous Vegetation	CEGL005264
Hesperostipa comata - Bouteloua gracilis - Carex filifolia Herbaceous Vegetation	Needle-and-thread - Blue Grama - Threadleaf Sedge Herbaceous Vegetation	CEGL002037
Pascopyrum smithii - Bouteloua gracilis - Carex filifolia Herbaceous Vegetation	Western Wheatgrass - Blue Grama - Threadleaf Sedge Herbaceous Vegetation	CEGL001579
Poa pratensis - (Pascopyrum smithii) Semi-natural Herbaceous Vegetation	Kentucky Bluegrass - (Western Wheatgrass) Semi-natural Herbaceous Vegetation	CEGL005265
Thinopyrum intermedium Semi-natural Herbaceous Vegetation	Intermediate Wheatgrass Semi-natural Herbaceous Vegetation	CEGL002935
Northern Mixed Grass Prairie: Forblands		
Polygonum spp. - Mixed Forbs Herbaceous Vegetation	Smartweed Species - Mixed Forbs Herbaceous Vegetation	CEGL002430
Northern Mixed Grass Prairie: Mesic Grasslands		
Distichlis spicata - Hordeum jubatum - Puccinellia nuttalliana - Suaeda calceoliformis Herbaceous Vegetation	Saltgrass - Foxtail Barley - Nuttail's Alkali Grass - Seablite Herbaceous Vegetation	CEGL002273
Panicum virgatum - (*Pascopyrum smithii*) Herbaceous Vegetation	Switchgrass - (Western Wheatgrass) Herbaceous Vegetation	CEGL001484
Phragmites australis Western North America Temperate Semi-natural Herbaceous Vegetation	Common Reed Western North America Temperate Semi-natural Herbaceous Vegetation	CEGL001475
Spartina pectinata - Carex spp. Herbaceous Vegetation	Prairie Cordgrass - Sedge species Herbaceous Vegetation	CEGL001477

Great Plains Wetland: Herbaceous Vegetation		
Carex nebrascensis Herbaceous Vegetation	Nebraska Sedge Herbaceous Vegetation	CEGL001813
Juncus balticus Herbaceous Vegetation	Baltic Rush Herbaceous Vegetation	CEGL001838
Schoenoplectus acutus - Typha latifolia - (Schoenoplectus tabernaemontani) Sandhills Herbaceous Vegetation	Hardstem Bulrush - Broadleaf Cattail - (Softstem Bulrush) Sandhills Herbaceous Vegetation	CEGL002030
Schoenoplectus pungens Herbaceous Vegetation	Threesquare Bulrush Herbaceous Vegetation	CEGL001587
Typha spp. Great Plains Herbaceous Vegetation	Cattail species Great Plains Herbaceous Vegetation	CEGL002389
Northern Mixed Grass Prairie: Upland Shrublands		
Symphoricarpos occidentalis Shrubland	Western Snowberry Shrubland	CEGL001131
Northern Mixed Grass Prairie: Mesic Shrublands		
Salix exigua / Mesic Graminoids Shrubland	Sandbar Willow / Mesic Graminoids Shrubland	CEGL001203
Northern Mixed Grass Prairie: Mesic Woodlands		
Salix amygdaloides Woodland	Peachleaf Willow Woodland	CEGL000947

*ELCODE represents NatureServe/TNC's internal NVCS database code (CEGL) for each vegetation association.

3.2 Photo-interpretation and Map Units

We recognized and delineated 60 map units on the color infrared aerial photographs for LNWR. This included 43 vegetation land-cover units and 17 Anderson (1976) Level II and 'Sub-level' II (more detailed units than Level II) land-use units (**Table 4**). The map units were developed from a combination of an initial NVCS vegetation classification provided by NatureServe with input from Refuge biologists and BOR ecologists, fieldwork, and preliminary photo-interpretation.

Included below are brief descriptions of the vegetation map units for LNWR as viewed in the field and from an overhead perspective. Please reference **Appendix G.** for photo-signature descriptions and representative photos for all vegetation map units.

Northern Mixed Grass Prairie: Animal Unit

1.0 Prairie Dog Town Complex
Prairie dog towns are found on deep, well-drained soils. The vegetation found on the prairie dog towns is somewhat variable depending primarily on the types of plant associations and agricultural activities that are in close proximity. Usually, the prairie dog towns are a mixture of areas of long-term established burrows, areas where the town is expanding, and areas of abandoned burrows. Collectively, this produces a fairly complex and patchy mosaic of vegetation. The result is usually a mix of introduced perennial graminoids that include smooth brome, Kentucky bluegrass, and crested wheatgrass (*Agropyron cristatum*) as well as a few species of native grasses such as western wheatgrass. The burrowing and grazing activities of the prairie dogs also provide bare soil for weedy plants that include dog fennel (*Dyssodia papposa*), Russian thistle (*Salsola iberica*) Canada thistle (*Cirsium arvense*), annual sunflower (*Helianthus annuus*), and white sweet clover (*Melilotus officinalis*).

Nebraska Sandhills Vegetation
The Sandhills region of northwestern Nebraska extends about a mile into the southern portion of the Refuge, covering approximately 28% (4500 acres) of LNWRs total area. This area is characterized by rolling terrain and stable sand deposits supporting a variety of common graminoids and shrubs, primarily prairie sandreed (*Calamovilfa longifolia*), sand bluestem (*Andropogon hallii*), needle-and-thread (*Hesperostipa comata*), and Soapweed yucca (*Yucca glauca*). Other species include sun sedge (*Carex inops* ssp. *Heliophila*), prairie junegrass (*Koeleria macrantha*), little bluestem (*Schizachyrium scoparium*), hairy grama (*Bouteloua hirsuta*), blue grama (*B.* gracilis), and sand dropseed (*Sporobolus cryptandrus*). There are six map units in this group.

2.1 Soapweed Yucca (Sparse Understory) Shrub Herbaceous Vegetation,
2.2 Soapweed Yucca / Prairie Sandreed Shrub Herbaceous Vegetation,
3.1 Needle-and-Thread / Soapweed Herbaceous Vegetation
Cover values for soapweed yucca shrubs ranges between 5-30% in these types. Cover and density of soapweed yucca tends to be highest on north facing slopes. While species composition may vary, overall foliar cover of the herbaceous vegetation is usually consistent. The most common grasses include prairie sandreed, sand bluestem, and needle-and-thread. Using the relatively consistent signature that soapweed densities provided, an attempt was made to separate it into three map classes based on shrub density and associated species.

Table 4. Map units and related levels within the NVCS or Land-use classification for Lacreek NWR. (Map units are organized by Ecological Groups.)

Map Class	Map Unit Name	Map Unit Common Name	Level
Northern Mixed Grass Prairie: Animal Units			
1.0	Blacktailed Prairie Dog Town Grassland Complex	Blacktailed Prairie Dog Town Grassland Complex	Association
Sandhills Vegetation			
2.1	*Yucca glauca* (Sparse Understory) Shrub Herbaceous Vegetation	Soapweed Yucca (Sparse Understory) Shrub Herbaceous Vegetation	Floristic Sub-Association
2.2	*Yucca glauca / Hesperostipa comata* Shrub Herbaceous Vegetation	Soapweed Yucca / Needle-and-thread Shrub Herbaceous Vegetation	Floristic Sub-Association
3.1	*Hesperostipa comata / Yucca glauca* Herbaceous Vegetation	Needle-and-thread / Soapweed Yucca Herbaceous Vegetation	Floristic Sub-Association
3.2	*Calamovilfa longifolia - Hesperostipa comata* Herbaceous Vegetation	Prairie Sandreed - Needle-and-thread Herbaceous Vegetation	Floristic Sub-Association
3.3	*Calamovilfa longifolia - Carex inops ssp. heliophila* Herbaceous Vegetation.	Prairie Sandreed - Sun Sedge Herbaceous Vegetation	Association
4.0	*Schizachyrium scoparium - Bouteloua (curtipendula, gracilis) - Carex filifolia* Herbaceous Vegetation	Little Bluestem - (Sideoats Grama, Blue Grama) - Threadleaf Sedge Herbaceous Vegetation	Association
Northern Mixed Grass Prairie: Upland Grasslands			
5.0	*Hesperostipa comata - Bouteloua gracilis - Carex filifolia* Herbaceous Vegetation	Needle-and-thread - Blue Grama - Threadleaf Sedge Herbaceous Vegetation	Association
6.0	*Andropogon gerardii - Panicum virgatum - Helianthus grosseserratus* Herbaceous Vegetation	Big Bluestem - Switchgrass - Sawtooth Sunflower Herbaceous Vegetation	Association
7.0	*Pascopyrum smithii - Bouteloua gracilis - Carex filifolia* Herbaceous Vegetation	Western Wheatgrass - Blue Grama - Threadleaf Sedge Herbaceous Vegetation	Association
8.0	*Poa pratensis - (Pascopyrum smithii)* Semi-natural Herbaceous Vegetation	Kentucky Bluegrass - (Western Wheatgrass) Semi-natural Herbaceous Vegetation	Association
9.0	*Bromus inermis - (Pascopyrum smithii)* Semi-natural Herbaceous Vegetation	Smooth Brome - (Western Wheatgrass) Semi-natural Herbaceous Vegetation	Association
10.0	*Agropyron cristatum - (Pascopyrum smithii, Hesperostipa comata)* Semi-natural Herbaceous Vegetation	Crested Wheatgrass - (Western Wheatgrass, Needle-and-Thread) Semi-natural Herbaceous Vegetation	Association
11.0	*Thinopyrum intermedium* Semi-Natural Herbaceous Vegetation	Intermediate Wheatgrass Semi-Natural Herbaceous Vegetation	Association
12.1	Mixed Grasslands	Mixed Grassland	*Complex/Association
12.2	Mixed Grassland (Warm Season Natives)	Mixed Grassland (Warm Season Natives)	Complex/Association
12.3	Mixed Grassland (Cool Season Natives)	Mixed Grassland (Cool Season Natives)	Complex/Association

Northern Mixed Grass Prairie: Forblands			
13.0	Mixed Forblands	Mixed Forblands	Complex/Association
14.0	*Cirsium arvense* Patches	Canada Thistle Patches	Association
15.0	*Glycyrrhiza lepidota* Stands	Wild Licorice Stands	Sub-Association
16.0	*Polygonum amphibum* Herbaceous Vegetation	Water Smartweed Herbaceous Vegetation	Association
Northern Mixed Grass Prairie: Mesic Grasslands			
17.0	*Panicum virgatum - (Pascopyrum smithii)* Herbaceous Vegetation	Switchgrass - (Western Wheatgrass) Herbaceous Vegetation	Association
18.1	*Hordeum jubatum* Herbaceous Vegetation	Foxtail Barley Herbaceous Vegetation	Floristic Sub-Association
18.2	*Distichlis spicata* Herbaceous Vegetation	Saltgrass Herbaceous Vegetation	Floristic Sub-Association
19.0	*Spartina pectinata - Carex spp.* Herbaceous Vegetation	Prairie Cordgrass - Sedge species Herbaceous Vegetation	Association
20.0	*Phragmites australis* Herbaceous Vegetation	Common Reed Herbaceous Vegetation	Association
Great Plains Wetland: Herbaceous Vegetation			
21.0	*Juncus balticus* Herbaceous Vegetation	Baltic Rush Herbaceous Vegetation	Association
22.0	*Carex nebrascensis* Herbaceous Vegetation	Nebraska Sedge Herbaceous Vegetation	Association
23.0	Emergent Sandhills Wetland	Emergent Sandhills Wetland	Alliance
24.0	*Schoenoplectus pungens* Herbaceous Vegetation	Threesquare Bulrush Herbaceous Vegetation	Association
25.0	*Schoenoplectus acutus - Typha latifolia - (Schoenoplectus tabernaemontani)* Sandhills Herbaceous Vegetation	Hardstem Bulrush - Broadleaf Cattail - (Softstem Bulrush) Sandhills Herbaceous Vegetation	Association
26.1	*Typha spp.* Great Plains Herbaceous Vegetation (Semipermanently Flooded)	Cattail species Great Plains Herbaceous Vegetation (Semipermanently Flooded)	Hydrology Sub-Association
26.2	*Typha spp.* Great Plains Herbaceous Vegetation (Seasonally Flooded)	Cattail species Great Plains Herbaceous Vegetation (Seasonally Flooded)	Hydrology Sub-Association
Northern Mixed Grass Prairie: Upland Shrublands			
27.0	*Symphoricarpos occidentalis* Shrubland	Western Snowberry Shrubland	Association

Northern Mixed Grass Prairie: Mesic Shrublands			
28.0	*Prunus americana* Stands	American Plum Stands	Association
29.0	*Amorpha fruticosa* Stands	False Indigobush Stands	Association
30.0	*Salix exigua / Mesic Graminoids* Shrubland	Sandbar Willow / Mesic Graminoids Shrubland	Association
Northern Mixed Grass Prairie: Mesic Woodlands			
31.0	*Celtis occidentalis* Stands	American Hackberry Stands	Association
32.0	*Salix amygdaloides* Woodland	Peachleaf Willow Woodland	Association
33.0	*Populus deltoides* Stands	Plains Cottonwood Stands	Association
34.0	*Fraxinus pennsylvanica* Stands	Green Ash Stands	Association
Northern Mixed Grass Prairie: Upland Grasslands (Planted)			
35.1	Native Species Plantings (*Bouteloua curtipendula*)	Native Species Plantings (Sideoats Grama)	Floristic Sub-Association
35.2	Native Species Plantings (*Mixed Grasses*)	Native Species Plantings (Mixed Grasses)	Complex/Association
35.3	Native Species Plantings (*Panicum virgatum*)	Native Species Plantings (Switchgrass)	Floristic Sub-Association
Agriculture			
40.0	Agricultural Lands	Agricultural Lands	Level I
41.0	Shelterbelt	Shelterbelt	Level II
Barren Lands			
42.0	Beach	Beach	Level II
43.0	Sandhills Blowout	Sandhills Blowout	Sub-Level II
Land-use and Transportation			
44.0	Bennett County Roads	Bennett County Roads	Sub-Level II
45.0	Refuge Management Roads	Refuge Management Roads	Sub-Level II
46.0	Levees (Flood Control)	Levees (Flood Control)	Sub-Level II
47.0	Dikes (Separate Impoundments)	Dikes (Separate Impoundments)	Sub-Level II

48.0	Cemetery	Cemetery	Level II
Ponds			
49.0	Ponds, impoundments	Ponds, impoundments	Sub-Level II
50.0	Ponds, Trout	Ponds, Trout	Sub-Level II
51.0	Ponds, potholes/dugout/stock	Ponds, potholes/dugout/stock	Sub-Level II
52.0	Pools	Pools	Sub-Level II
Streams and Rivers			
53.0	Lake Creek Channel	Lake Creek Channel	Sub-Level II
Built-up Lands			
54.0	Clay Pits	Clay Pits	Level II
55.0	Refuge Facilities	Refuge Facilities	Level II
56.0	Residential	Residential	Level II

***COMPLEX:** Individual associations are not recognizable on the aerial photographs but repeatedly occur together in the landscape**.** Complexes typically are composed of communities with similar physiognomies; thus are more difficult to tell apart on the photo.

3.2 Prairie sandreed – Needle-and-Thread Herbaceous Vegetation
Small stands are common throughout the sandhills; however, many are smaller than the minimum mapping unit of 0.5 ha. The most extensive stands of prairie sandreed occur primarily in the northeast corner of the sandhills (southeast corner of the Refuge) and often appear to serve as a transition between the sandhills and the mixed prairie on finer textured soils and wetlands to the north. Foliar cover for this association ranges from 20-40%. The dominant species is prairie sandreed, with sand bluestem, needle-and-thread, and Kentucky bluegrass (*Poa pratensis*) as common secondary species. Soapweed is often present but usually at low densities.

3.3 Prairie Sandreed – Sun Sedge Herbaceous Vegetation
These grasslands are intricately intermixed with the Prairie Sandreed – Needle-and-Thread Herbaceous Vegetation and the Soapweed yucca units. Cover of soapweed yucca shrubs is typically less than 5%. Prairie sandreed is the most common graminoid but sand bluestem appears to vary considerably and may be locally dominant. Common secondary species include needle-and-thread, sun sedge, sand dropseed, hairy grama, and prairie Junegrass. Forb cover and composition is highly variable. Sunflower (*Helianthus annuus*) was especially prominent during the 2001 field season.

4.0 Little Bluestem - Grama Grass (Sideoats, Blue) - Threadleaf Herbaceous Vegetation
This community type is restricted to moderately steep, north and east facing slopes in the sandhills. Vegetation cover is typically between 75 and 85% and is dominated by little bluestem. Cover by soapweed yucca varies, but is usually 10 to 20%. Although species richness can be relatively high, overall cover and frequency of associated species is exceptionally low. Needle-and-thread, prairie june grass (*Koeleria macrantha*), dotted gayfeather (*Liatris punctata*), and prairie sandreed are common associates.

Northern Mixed Grass Prairie: Upland Grasslands
The herbaceous vegetation units recorded on the Refuge are probably typical of managed mixed grass prairie types found throughout the northern Great Plains region. Introduced grass species, native prairie restoration, and mowing to control Canada thistle have modified many of the natural grasslands of the Refuge. Western wheatgrass (*Pascopyrum smithii*) is probably the most common native grass species on the Refuge. Stands of switchgrass (*Panicum virgatum*) and big bluestem (*Andropogon gerardii*) are widely scattered throughout. Ten map units make-up this group.

5.0 Needle-and-Thread - Blue Grama Grass - Threadleaf Sedge Herbaceous Vegetation
This unit is found only on a few localized areas on the Refuge. Stands occur on hill summits and on gentle slopes with loamy soils. Needle-and-thread, blue grama, and threadleaf sedge (*Carex filifolia*) are the major species, while sand dropseed and western wheatgrass are common secondary species. Total cover ranges from 40-70% depending primarily on the abundance of threadleaf sedge and blue grama. Japanese brome is a common invader on these sites.

6.0 Big Bluestem - Switchgrass - Sawtooth Sunflower Herbaceous Vegetation
This unit is widely scattered on mesic sites throughout the Refuge, except in the Sandhills portion. It is often closely associated with prairie cordgrass (*Spartina pectinata*) and switchgrass (*Panicum virgatum*) map units. Big bluestem also appears to be a common constituent of many prairie restoration efforts on the Refuge. Typical stands of this association have moderate to dense herbaceous cover with typical foliar cover values ranging from 50 to 100%. Big bluestem is the dominant species, becoming more prominent later in the growing season. Distribution of the species is often patchy within a stand, with associated species such as sawtooth sunflower (*Helianthus grosseserratus),* prairie cordgrass*,* smooth brome, and switchgrass occupying the interstitial spaces.

7.0 Western Wheatgrass - Blue Grama - Threadleaf Sedge Herbaceous Vegetation
Extensive stands of western wheatgrass are found on silty loam soils throughout the Refuge. Overall species richness in this community type is low. However, inland saltgrass (*Distichlis spicata*), blue grama, and Kentucky bluegrass are frequent associates.

Introduced, exotic grasslands occur throughout the Refuge and are sometimes associated with disturbances such as roadsides, abandoned farm fields, and areas that were interseeded with exotic grasses. However, exotic grasses can and do invade intact native communities. Exotic grasses often dominate areas that have been disturbed as a result of construction or agriculture. Exotic grasses, such as smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis),* crested wheatgrass (*Agropyron cristatum*) have invaded native grassland types, often becoming the dominant species. In some areas, the mixed grass prairie types form an intricate and intermixed transition zone between the sandhills vegetation types and the wetland types.

8.0 Kentucky Bluegrass - (Western Wheatgrass) Semi-natural Herbaceous Vegetation
The Kentucky bluegrass semi-natural association also occurs in a wide variety of habitats, including the Sandhills. Although stands can be monotypic, overall species richness is usually higher in this association than in other introduced grasslands. Litter accumulation is often very high in many stands.

9.0 Smooth Brome - (Western Wheatgrass) Semi-natural Herbaceous Vegetation
The smooth brome semi-natural map unit is probably the most common and widely distributed plant species on the Refuge. Stands occur in an exceptionally wide variety of habitats, with the exception of the Sandhills. The species was widely planted for soil stabilization and as part of the Conservation Reserve Program. It is a very aggressive exotic that has expanded into disturbed and undisturbed areas. These grasslands usually consist of a nearly monotypic stand of *Bromus inermis* that is usually less than 1 m in height. Well-developed stands have few, if any, associated species.

10.0 Crested Wheatgrass - (Western Wheatgrass, Needle-and-Thread) Semi-natural Herbaceous Vegetation
The crested wheatgrass semi-natural type is probably best represented on the upland grassland areas north and west of the Refuge headquarters. These grasslands are usually found on relatively level to gently rolling sites. Typically the soils are silt or clay loams that probably supported western wheatgrass grasslands in the past. Stands of crested wheatgrass typically have moderate herbaceous cover that ranges from 30 to 60%. Litter cover on the soil surface is often dense. The sites are dominated by crested wheatgrass with a host of invasive species such as Kentucky bluegrass and/or smooth brome. The forb component is usually very sparse.

11.0 Intermediate wheatgrass Semi-Natural Herbaceous Vegetation
The intermediate wheatgrass semi-natural type is only represented on a few sites in the Refuge. Stands of intermediate wheatgrass typically have moderate herbaceous cover that ranges from 30 to 60%. Litter cover on the soil surface is often dense. The sites are dominated by intermediate wheatgrass with other invasive species such as Kentucky bluegrass and/or smooth brome. The forb component is usually very sparse.

12.1, 12.2, 12.3 Mixed Native Species
35.1, 35.2, 35.2 Native Species Plantings
Historic land management practices resulted in different native species complexes scattered throughout the Refuge. In addition, restoration efforts have occurred throughout the Refuge at various times and produced several types. Some types have clear dominants such as side oats grama (*Bouteloua curtipendula*) and switchgrass. However, other sites have experienced secondary succession producing more complex vegetation types characterized by a mixture of species.

Northern Mixed Grass Prairie: Forbland

13.0 Mixed Forblands
This unit represents areas in and around the Refuge pools that support mixed weedy or annual forbs with little graminoid species. Areas are usually heavily disturbed from flooding.

14.0 Canada Thistle Patches
This unit is common throughout the Refuge in mesic grassland sites. Canada thistle usually contributes heavily to the cover, upwards of 100%, and may displace the native species. Mowing to control the spread of this type is evident in large patches.

15.0 Wild Licorice Stands
This map unit is rare on the Refuge and restricted to only a few sites around the Refuge Pools. Wild licorice (*Glycyrrhiza lepidota*) is clearly the dominant in these sites with very little associated species.

16.0 Smartweed Species - Mixed Forbs Herbaceous Vegetation
This association is common to drawdown and mudflat areas around the Refuge. The soils are usually saturated and support mixed weedy or annual forbs with little graminoid species. Diversity is usually low and association composition likely varies from season to season and year to year.

Northern Mixed Grass Prairie: Mesic Grasslands

17.0 Switchgrass – (Western Wheatgrass) Herbaceous Vegetation
This association occurs on upland sites throughout the Refuge, including isolated patches in sandhill swales and depressions. Well-developed examples also occur on sites adjacent to wetland community types. The switchgrass herbaceous vegetation type provides ground cover values of between 50 and 80%. Switchgrass and big bluestem are the dominant species, especially in mesic areas, while western wheatgrass is more abundant on drier sites. Common associated species include wild licorice and Kentucky bluegrass. Where the type occurs in the sandhills, the distribution becomes patchy and bordered by prairie sandreed, needle-and-thread, and soapweed yucca shrubs. Smooth brome is a major invader in sites adjacent to the Sandhills, resulting in complex mosaics of switchgrass and smooth brome.

18.1 Foxtail Barely Herbaceous Vegetation
18.2 Saltgrass Herbaceous Vegetation
These units occupy flat, alkaline, silt loam soils near the Refuge pools on sites that are poorly to moderately well-drained. The fluctuating water table is probably within the rooting zone of the vegetation for most of the growing season. In many cases, this association is fairly monotypic and dominated by inland saltgrass (*Distichlis spicata*). Total foliar cover is usually less than 50% and vegetation height is often less than 15 cm. The most common secondary species is Kentucky bluegrass. Small depressions often contain nearly pure stands of foxtail barley (*Hordeum jubatum*).

19.0 Prairie Cordgrass – Sedge Species Grassland
The prairie cordgrass (*Spartina pectinata*) vegetation type occurs throughout the Refuge where the soil is wet for at least part of the growing season, including the sandhills portion. Large stands grow between the cattail and inland saltgrass *a*ssociations Refuge pools. Smaller stands, most less than 0.5 ha in size, are found in isolated depressions in the sandhills. Foliar cover is typically high (75-100%) in most stands and dominated by prairie cordgrass between 0.5 m to 1 m tall. Associated vegetation varies with location of the stand. Typically, cattail species are common constituents in mesic areas near Refuge pools, while big bluestem and switchgrass frequently grow on drier upland sites and in the sandhills.

20.0 Common Reed Western North America Temperate Semi-natural Herbaceous Vegetation
This is a rare association at LNWR that only occurs in a few small stands. The association is characterized by having dense cover of common reed and little overall species diversity.

Great Plains Wetlands: Herbaceous Vegetation

21.0 Baltic Rush Herbaceous Vegetation
Baltic rush (*Juncus balticus*) stands are rare and patchy within the Refuge. Stands are usually less than 0.5 ha in size and occur in poorly drained sites where the soil is saturated for most of the growing season. The stands are characterized by a dense cover of Baltic rush with cattail species and prairie cordgrass as minor components of the association.

22.0 Nebraska Sedge Herbaceous Vegetation
The distribution of this type on the Refuge is extremely patchy. Most stands are smaller the minimum mapping unit of 0.5 ha. Stands usually occur in poorly drained sites adjacent to wetlands and near small drainages with few, if any, associated species. Soils are saturated and intermittently flooded for most of the growing season. A few scattered peachleaf willow trees occur in one stand adjacent to Elm Creek.

24.0 Three-square Bulrush Herbaceous Vegetation
This rare unit is comprised of stands that are less than 0.5 ha in size. Stands of this community type occur in small, isolated depressions where the water table intersects the surface. Hydrologic conditions are very similar to those of the Hardstem bulrush type (map unit 25.0). The vegetation is typically 0.5 to 2 m in height with foliar cover approaching 100%.

25.0 Hardstem Bulrush – Broadleaf Cattail – (Softstem Bulrush) Sandhills Herbaceous Vegetation
The vast majority of the stands that characterize this map unit are less than 0.5 ha in size. Stands of this community type occur in small, isolated depressions where the water table intersects the surface. The soils are intermittently saturated; however, the amount of moisture probably fluctuates considerably from one year to the next. The vegetation is typically 1 to 2 m in height with foliar cover approaching 100%. Because this community is restricted to very small, isolated depressions, the size of the stands probably fluctuates seasonally as well as from one year to the next. Cattail (*Typha latifolia*) is the most common secondary species.

26.1 Cattail Species Great Plains Herbaceous Vegetation (Semipermanently Flooded)
26.1 Cattail Species Great Plains Herbaceous Vegetation (Seasonally Flooded)
Cattail stands are found throughout intermittently flooded areas adjacent to Refuge pools, ponds, dugouts, and drainages. Foliar cover typically approaches 100% and plants are usually 2 to 2.5 m in height. Bulrush, Canada thistle (*Cirsium arvense*), and sow thistle (*Sonchus arvensis*) are frequent constituents.

Northern Mixed Grass Prairie: Upland Shrublands

27.0 Western Snowberry Shrubland
Western snowberry shrublands are rare within the Refuge. Only a few small stands (less than 0.5 ha in size) were recorded in the northernmost portion of the Refuge. Western snowberry is generally found on sites that receive some form of supplemental moisture. Consequently, they are usually associated with small depressions in the uplands. At the Refuge, the stands are often intermixed with, a wide variety of vegetation types such as western wheatgrass and other upland grasses.

Northern Mixed Grass Prairie: Mesic Shrublands

Naturally occurring, well-developed shrublands and woodlands are relatively rare at LNWR making them important for monitoring and management concerns. For this reason, all sites regardless of size were sampled, classified, and mapped with varying success. Stands were usually considerably smaller than the minimum mapping unit of 0.5 ha and were extremely difficult to identify on the aerial photographs. Due to their small size and limited distributions most shrub and tree map units were primarily mapped during on-ground surveys resulting in map units that resemble, but are not true plant associations.

28.0 American Plum Stands

Stands of American plum occupy many sites throughout the more mesic portions of the Refuge. In many cases, stands are closely associated with shelterbelts along county roads. American plum also occurs as isolated patches in grassland types and as linear stands along dikes and levees. Stands usually occur as dense, almost impenetrable thickets with foliar cover approaching 100%. Common understory includes weedy species such as catnip (*Nepeta cataria*), Canada thistle (*Cirsium arvense*), and Japanese brome (*Bromus japonicus*). Wild licorice (*Glycyrrhiza lepidota*) is also a frequent constituent.

29.0 Indigo Bush Stands

These shrublands often form dense stands that border Lake Creek. Height of the shrubs is usually about 2 m and foliar cover ranges from 60 to 80%. The understory vegetation is typically dominated by smooth brome and prairie cordgrass.

30.0 Sandbar Willow / Mesic Graminoids Shrubland

The sandbar willow / mesic graminoids shrubland occurs as scattered stands near the edges of ponds, and along dike, levee, and roadway edges throughout the Refuge, except for the sandhills portion. Typical stands of sandbar willow are 1-3 m tall with dense interlocking canopies that approach 100% foliar cover. Stands are usually devoid of understory vegetation; however, prairie cordgrass and cattail (*Typha)* are sometimes found in close association. An occasional individual peachleaf willow (*Salix amygdaloides)* tree sometimes occurs adjacent to the stands and is recorded as an overstory species.

Northern Mixed Grass Prairie: Mesic Woodlands

31.0 American Hackberry Stands
32.0 Peachleaf Willow Woodland
33.0 Plains Cottonwood Stands
34.0 Green Ash Stands

These map units represent rare wooded areas within the Refuge. In most cases, all units are smaller than the minimum mapping unit. Peachleaf willow is the most abundant and represents a true woodland association. This type is widely scattered in small stands throughout the Refuge, except for the sandhills portion. Many of the stands are less than 0.5 ha in size and occupy a range of mesic sites in close association with wetland communities dominated by prairie cordgrass, cattail, and Nebraska sedge (*Carex nebrascensis*). The peachleaf willow association typically occurs as three to six trees clustered together to form a dense canopy. These clusters sometimes appear to have coalesced to form a larger stand. Total foliar cover values range from 60 to 100%. The lower values occur where canopies between the stands do not overlap. Individual trees were generally large (10-15 m tall) and mature. Understory shrubs were not common.

3.3 Relationship Between Lacreek NWR Map Units and NVCS

The LNWR map units represent a compromise among the detail of the NVCS classification, the needs of the Refuge and the limitations of the photography. As a result, the LNWR mapping scheme does not exactly match the NVCS. The vegetation map units are linked ("crosswalked") to the NVCS plant associations (**Appendix E**). When a plant association had a unique photo signature, the map unit and the plant association are the same. When plant associations occurred in complexes of stands too small to map or when related plant associations shared the same signature, several plant associations might be lumped into a single map unit. When more than one phase of a single plant association could be recognized on the photos, a plant association would be split among several map classes. Finally, non-vegetated areas and vegetation types not recognized by the NVCS received special map unit designations.

Map Units Representing Associations (one to one)

The following map units were created from the NVCS associations and represent single types that could be discerned and delineated on the aerial photography. The cross-walking of these map units is on a one map unit to one NVCS association basis.

Map Class Map Unit
NVCS Association

1.0 Blacktailed Prairie Dog Town Grassland Complex
Blacktailed Prairie Dog Town Grassland Complex

3.3 Prairie Sandreed - Sun Sedge Herbaceous Vegetation
Calamovilfa longifolia - Carex inops ssp. heliophila Herbaceous Vegetation.

4.0 Little Bluestem - (Sideoats Grama, Blue Grama) - Threadleaf Sedge Herbaceous Vegetation
Schizachyrium scoparium - Bouteloua (curtipendula, gracilis) - Carex filifolia Herbaceous Vegetation

5.0 Needle-and-thread - Blue Grama - Threadleaf Sedge Herbaceous Vegetation
Hesperostipa comata - Bouteloua gracilis - Carex filifolia Herbaceous Vegetation

6.0 Big Bluestem - Switchgrass - Sawtooth Sunflower Herbaceous Vegetation
Andropogon gerardii - Panicum virgatum - Helianthus grosseserratus Herbaceous Vegetation

7.0 Western Wheatgrass - Blue Grama - Threadleaf Sedge Herbaceous Vegetation
Pascopyrum smithii - Bouteloua gracilis - Carex filifolia Herbaceous Vegetation

8.0 Kentucky Bluegrass - (Western Wheatgrass) Semi-natural Herbaceous Vegetation
Poa pratensis - (Pascopyrum smithii) Semi-natural Herbaceous Vegetation

9.0 Smooth Brome - (Western Wheatgrass) Semi-natural Herbaceous Vegetation
Bromus inermis - (Pascopyrum smithii) Semi-natural Herbaceous Vegetation

10.0 Crested Wheatgrass - (Western Wheatgrass, Needle-and-Thread) Semi-natural Herbaceous Veg.
Agropyron cristatum - (Pascopyrum smithii, Hesperostipa comata) Semi-natural Herbaceous Vegetation

11.0 Intermediate Wheatgrass Semi-Natural Herbaceous Vegetation
Thinopyrum intermedium Semi-natural Herbaceous Vegetation

16.0 Water Smartweed Herbaceous Vegetation
Polygonum spp. - Mixed Forbs Herbaceous Vegetation

17.0 Switchgrass - (Western Wheatgrass) Herbaceous Vegetation
Panicum virgatum - (Pascopyrum smithii) Herbaceous Vegetation

19.0 Prairie Cordgrass - Sedge species Herbaceous Vegetation
Spartina pectinata - Carex spp. Herbaceous Vegetation

20.0 Common Reed Herbaceous Vegetation
Phragmites australis Western North America Temperate Semi-natural Herbaceous Vegetation

21.0 Baltic Rush Herbaceous Vegetation
Juncus balticus Herbaceous Vegetation

22.0 Nebraska Sedge Herbaceous Vegetation
Carex nebrascensis Herbaceous Vegetation

24.0 Threesquare Bulrush Herbaceous Vegetation
Schoenoplectus pungens Herbaceous Vegetation

25.0 Hardstem Bulrush - Broadleaf Cattail - (Softstem Bulrush) Sandhills Herbaceous Vegetation
Schoenoplectus acutus - Typha latifolia - (Schoenoplectus tabernaemontani) Sandhills Herbaceous Vegetation

27.0 Western Snowberry Shrubland
Symphoricarpos occidentalis Shrubland

30.0 Sandbar Willow / Mesic Graminoids Shrubland
Salix exigua / Mesic Graminoids Shrubland

32.0 Peachleaf Willow Woodland
Salix amygdaloides Woodland

Map Units Representing Floristic or Physiographic Change (many to one)

The following map units have been separated from a single plant association due to either floristic (*i.e.* one species is clearly dominate over another in the association) or physiographic (*i.e.* differences can be detected in the substrate or hydrology that influences the association) differences. For floristic splits the dominant species in the NVCS association varies across the Refuge and this shift is clearly recognizable both in the field and on the photography. This change in dominance likely results from a combination of management, substrate, or moisture differences. Map units used to delineate these types can be considered a sub-set of the association representing only one plant species (indicated in the NVCS association below with an underline).

Map units split from one NVCS association based on physiographic changes are based on the ability to discern and delineate subtle changes in the association caused by differences in the hydrologic regime. This change is represented as separate map units with only a different modifier indicating the physiographic condition (*e.g.* seasonally flooded). The cross-walking of these map units to the NVCS is on a multiple map unit to one NVCS association basis.

Map Class	Map Unit *NVCS Association*
Floristic	
	2.1 Soapweed Yucca (Sparse Understory) Shrub Herbaceous Vegetation *Yucca glauca / Calamovilfa longifolia Shrub Herbaceous Vegetation*
	2.2 Soapweed Yucca / Needle-and-thread Shrub Herbaceous Vegetation *Yucca glauca / Calamovilfa longifolia Shrub Herbaceous Vegetation*
	3.1 Needle-and-thread / Soapweed Yucca Herbaceous Vegetation *Calamovilfa longifolia - Hesperostipa comata Herbaceous Vegetation*
	3.2 Prairie Sandreed - Needle-and-thread Herbaceous Vegetation *Calamovilfa longifolia - Hesperostipa comata Herbaceous Vegetation*
	18.1 Foxtail Barley Herbaceous Vegetation *Distichlis spicata - Hordeum jubatum - Puccinellia nuttalliana - Suaeda calceoliformis Herbaceous Vegetation*
	18.2 Saltgrass Herbaceous Vegetation *Distichlis spicata - Hordeum jubatum - Puccinellia nuttalliana - Suaeda calceoliformis Herbaceous Vegetation*
Physiographic	
	26.1 Cattail species Great Plains Herbaceous Vegetation (Semipermanently Flooded) *Typha spp. Great Plains Herbaceous Vegetation*
	26.2 Cattail species Great Plains Herbaceous Vegetation (Seasonally Flooded) *Typha spp. Great Plains Herbaceous Vegetation*

Map Units Representing No Association (refuge specials)

The management needs at LNWR were of great concern to Refuge staff, especially land-use history and vegetation management records. For example, a clearly defined polygon was classified as Western wheatgrass - blue grama - threadleaf sedge Herbaceous Vegetation type according to the fieldwork and the NVCS. Part of this polygon was then reassessed by LNWR as a mix of cool season native grasses due to restoration or seeding efforts. Technically, labels are correct and important to their respective contexts. To address these differences in classification, two solutions were implemented at LNWR: "Refuge Specials" and, U.S. Fish and Wildlife Service (FWS) modifiers.

Refuge Special types were created for LNWR for one of the following reasons:

- To represent important wildlife habitat types not known outside the Refuge;
- To represent important wildlife habitat types occurring in patches smaller than the minimum mapping unit of 0.5 ha;
- To represent vegetation that was manipulated in the recent past. This includes native species plantings and truly mixed grasslands that could not be classified to an NVCS association.

Map Class	Map Unit Explanation

12.1 Mixed Grassland
This type has either been planted or manipulated and has no clear dominant species.

12.2 Mixed Grassland (Warm Season Natives)
This type has either been planted or manipulated and has no clear dominant species.

12.3 Mixed Grassland (Cool Season Natives)
This type has either been planted or manipulated and has no clear dominant species.

13.0 Mixed Forbland
This type contains many different forb species with no clear dominants to be classified.

14.0 Canada Thistle Patches*
Only occurs on the Refuge in limited areas, always in conjunction with an association and can't be classified due to its spreading throughout multiple vegetation types.

15.0 Wild Licorice Stands*
Only occurs on the Refuge in limited areas, too small to classify as an association.

23.0 Emergent Sandhills Wetland
Only occurs on the Refuge in limited areas, no clear dominant or associated species to classify.

28.0 American Plum Stands*
Only occurs on the Refuge in limited areas, too small to classify as an association.

29.0 False Indigobush Stands*
Only occurs on the Refuge in limited areas, too small to classify as an association.

31.0 American Hackberry Stands*
Only occurs on the Refuge in limited areas, too small to classify as an association.

33.0 Plains Cottonwood Stands*
Only occurs on the Refuge in limited areas, no clear associated species and too small to classify as an association.

34.0 Green Ash Stands*
Only occurs on the Refuge in one area, too small to classify as an association.

35.1 Native Species Plantings (Sideoats Grama)
This type is a planted monoculture with few other species present.

35.2 Native Species Plantings (Mixed Grasses)
This type has been planted and has no clear dominant species.

35.3 Native Species Plantings (Switchgrass)
This type is a planted monoculture with few other species present.

(*Patches and Stands indicate likely NVCS associations that did not occur in sufficient size or frequency to be considered a valid community (association).

FWS Modifiers are additional vegetation attributes recorded on the photography and incorporated into the GIS spatial data layer. These attributes acknowledged LNWR vegetation names for a polygon as well as maintaining the NVCS association name. In this manner both types can be queried for analysis and an overlay pattern can be used for presentation purposes. The following were FWS modifier names used to indicate differences in classification:

- Blue Grama (*Bouteloua gracilis*) Grazed Grassland
  (This type was used to indicate areas that were grazed by cattle causing blue grama to become the dominant species in the NVCS association).

- Canada Bluegrass (*Poa compressa*) Introduced Grassland
  (This type was used to indicate areas that were planted by the Refuge to Canada bluegrass but was either not the dominant or was not apparent in the field.)

- Mixed Brome - Mixed Native Grassland
  (This type was used to indicate areas that had a large component of smooth brome (*Bromus inermis*), cheatgrass (*B. tectorum*) and/or Japanese brome (*B. japonicus*). These areas were classified in the field to an NVCS association based on the native grass component.)

- Mixed Cool Season - Native Grassland
  (This type was used to indicate areas that had a large component of mixed cool season natives, both native and non-native. These areas were classified in the field to an NVCS association based on the native grass component.)

3.4 Vegetation Map

A total area of 21,950 acres (8883 ha) comprising LNWR was mapped, including acreage owned or leased by the State of South Dakota and private individuals. Of this total, NVCS-related vegetation map units covered about 16,633 acres. The remaining acreage was mapped using land cover and Refuge special map units. Of all the map units, the most frequent was Peachleaf willow Woodland (164 polygons). However these were typically quite small (0.7 acres). The most abundant map unit in terms of area was Refuge Pools, (map unit 52.0) covering 2,152 acres. Frequencies of map units (*i.e.* number of polygons) along with acreage per map unit are listed in **Table 5**.

Deer at Lacreek National Wildlife Refuge

Table 5. Acreage and frequency of map units for Lacreek National Wildlife Refuge summarized by ownership.

Map Class	Map Unit Common Name	Refuge* Polygons	State Polygons	Total Polygons	Refuge* Acres	State Acres	Total Acres	Ave Total (a)	Total Hectares	Ave Total (h)
1.0	Blacktailed Prairie Dog Town Grassland Complex	9	4	13	159.6	44.7	204.3	15.7	82.7	6.4
2.1	Soapweed Yucca (Sparse Understory) Shrub Herbaceous Vegetation	107	13	120	992.4	49.5	1041.9	8.7	421.7	3.5
2.2	Soapweed Yucca / Needle-and-thread Shrub Herbaceous Vegetation	36	0	36	243.1	0	243.1	6.8	98.4	2.7
3.1	Needle-and-thread / Soapweed Yucca Herbaceous Vegetation	79	1	80	974.0	1.0	975.0	12.2	394.6	4.9
3.2	Prairie Sandreed - Needle-and-thread Herbaceous Vegetation	38	2	40	618.2	0.8	619.0	6.5	250.5	6.3
3.3	Prairie Sandreed – Sun Sedge Herbaceous Vegetation	25	4	29	1679.8	142.3	1822.1	62.8	737.4	25.4
4.0	Little Bluestem - (Sideoats Grama, Blue Grama) - Threadleaf Sedge Herbaceous Vegetation	6	1	7	2.4	0.3	2.7	0.4	1.1	0.2
5.0	Needle-and-thread - Blue Grama - Threadleaf Sedge Herbaceous Vegetation	3	0	3	9.1	0	9.1	3.0	3.7	1.2
6.0	Big Bluestem - Switchgrass - Sawtooth Sunflower Herbaceous Vegetation	6	0	6	214.3	0	214.3	35.7	86.7	14.5
7.0	Western Wheatgrass - Blue Grama - Threadleaf Sedge Herbaceous Vegetation	25	15	40	445.4	408.9	854.3	21.4	345.7	8.6
8.0	Kentucky Bluegrass - (Western Wheatgrass) Semi-natural Herbaceous Vegetation	70	2	72	971.2	36.8	1008.0	14.0	407.9	5.7
9.0	Smooth Brome - (Western Wheatgrass) Semi-natural Herbaceous Vegetation	122	38	160	1530.7	333.5	1864.2	11.7	754.4	4.7
10.0	Crested Wheatgrass - (Western Wheatgrass, Needle-and-Thread) Semi-natural Herbaceous Vegetation	31	2	33	931.0	6.1	937.1	28.4	379.2	11.5
11.0	Intermediate Wheatgrass Semi-Natural Herbaceous Vegetation	5	1	6	14.8	42.2	57.0	9.5	23.1	3.8
12.1	Mixed Grassland	2	7	9	20.8	56.3	77.1	8.6	31.2	3.5
12.2	Mixed Grassland (Warm Season Natives)	9	0	9	556.3	0	556.3	61.8	225.1	25.0
12.3	Mixed Grassland (Cool Season Natives)	2	0	2	168.7	0	168.7	84.4	68.3	34.1
13.0	Mixed Forbland	90	15	105	1302.8	218.7	1521.5	14.5	615.8	5.9
14.0	Canada Thistle - Weedy Forb Great Plains Herbaceous Vegetation (Provisional)	6	0	6	5.0	0	5.0	0.8	2.0	0.3
15.0	Wild Licorice Stands	28	5	33	63.5	6.2	69.7	2.1	28.2	0.9
16.0	Water Smartweed Herbaceous Vegetation	21	5	26	126.3	17.1	143.4	5.5	58.0	2.2

Map Class	Map Unit Common Name	Refuge* Polygons	State Polygons	Total Polygons	Refuge* Acres	State Acres	Total Acres	Ave Total (a)	Total Hectares	Ave Total (h)
17.0	Switchgrass - (Western Wheatgrass) Herbaceous Vegetation	49	0	49	67.1	0	67.1	1.4	27.2	0.6
18.1	Foxtail Barley Herbaceous Vegetation	8	1	9	17.1	2.3	19.4	2.2	7.9	0.9
18.2		67	11	78	483.3	78.8	562.1	7.2	227.5	2.9
19.0	Prairie Cordgrass - Sedge species Herbaceous Vegetation	122	48	170	732.0	154.8	886.8	5.2	358.9	2.1
20.0	Common Reed Herbaceous Vegetation	12	0	12	21.5	0	21.5	1.8	8.7	0.7
21.0	Baltic Rush Herbaceous Vegetation	6	0	6	28.2	0		4.7	11.4	1.9
22.0	Nebraska Sedge Herbaceous Vegetation	6	1	7	7.3	0.1	7.4	1.1	3.0	0.4
23.0	Marsh Spikerush Herbaceous Vegetation	8	0	8	12.9	0	12.9	1.6	5.2	0.7
24.0	Threesquare Bulrush Herbaceous Vegetation	2	0	2	14.6	0	14.6	7.3	5.9	3.0
25.0	Hardstem Bulrush - Broadleaf Cattail - (Softstem Bulrush) Sandhills Herbaceous Vegetation	15	0	15	39.8	0	39.8	2.7	16.1	1.1
26.1	Cattail species Great Plains Herbaceous Vegetation (Semipermanently Flooded)	123	6	129	1612.6	16.7	1629.3	12.6	659.4	5.1
26.2	Cattail species Great Plains Herbaceous Vegetation (Seasonally Flooded)	130	16	146	681.3	76.6	757.9	5.2	306.7	2.1
27.0	Western Snowberry Shrubland	3	0	3	0.4	0	0.4	0.1	0.2	0.1
28.0	American Plum Stands	27	0	27	7.6	0	7.6	0.3	3.1	0.1
29.0	False Indigobush Stands	6	0	6	34.5	0	34.5	5.8	14.0	2.3
30.0	Sandbar Willow / Mesic Graminoids Shrubland	36	3	39	26.3	0.7	27.0	0.7	10.9	0.3
31.0	American Hackberry Stands	2	0	2	0.5	0.0	0.5	0.3	0.2	0.1
32.0	Peachleaf Willow Woodland	164	14	178	104.0	14.2	118.2	0.7	47.8	0.3
33.0	Plains Cottonwood Woodland	4	0	4	2.3	0	2.3	0.6	0.9	0.2
34.0	Green Ash Stand	1	0	1	2.2	0	2.2	2.2	0.9	0.9
35.1	Native Species Plantings (Sideoats Grama)	1	0	1	19.1	0	19.1	19.1	7.7	7.7
35.2	Native Species Plantings (Mixed Grasses)	12	1	13	530.0	0.1	530.1	40.8	214.5	16.5

Map Class	Map Unit Common Name	Refuge* Polygons	State Polygons	Total Polygons	Refuge* Acres	State Acres	Total Acres	Ave Total (a)	Total Hectares	Ave Total (h)
35.3	Native Species Plantings (Switchgrass)	19	3	22	156.3	1.5	157.8	7.2	63.9	2.9
40.0	Agricultural Lands	8	22	30	306.7	1457.0	1763.7	58.8	713.8	23.8
41.0	Shelterbelt	26	11	37	83.7	40.2	123.9	3.3	50.1	1.4
42.0	Beach	4	0	4	4.1	0	4.1	1.0	1.7	0.4
43.0	Sandhills Blowout	16	4	20	16.6	0.8	17.4	0.9	7.0	0.4
44.0	Bennett County Roads	4	4	8	136.9	22.0	158.9	19.9	64.3	8.0
45.0	Refuge Management Roads	4	0	4	17.7	0	17.7	4.4	7.2	1.8
46.0	Levees (Flood Control)	1	0	1	3.1	0	3.1	3.1	1.3	1.3
47.0	Dikes (Separate Impoundments)	4	0	4	6.0	0	6.0	1.5	2.4	0.6
48.0	Cemetery	1	0	1	2.3	0	2.3	2.3	0.9	0.9
49.0	Ponds, impoundments	13	1	14	10.1	0.6	10.7	0.8	4.3	0.3
50.0	Ponds, Trout	10	0	10	10.9	0	10.9	1.1	4.4	0.4
51.0	Ponds, potholes/dugout/stock	26	27	53	141.0	54.2	195.2	3.7	79.0	1.5
52.0	Pools	74	0	74	2152.3	0	2152.3	29.1	871.0	11.8
53.0	Lake Creek Channel	9	0	9	9.5	0	9.5	1.1	3.8	0.4
54.0	Clay Pits	8	3	11	8.8	1.0	9.8	0.9	4.0	0.4
55.0	Refuge Facilities	5	0	5	13.9	0	13.9	2.8	5.6	1.1
56.0	Residential	5	9	14	45.7	63.9	109.6	7.8	44.4	3.2
Totals										
	All Map Units	1,761	300	2,061	18,599.6	3,349.9	21,949.5	687.6	8,883.0	278.3
	Natural/Semi-natural Vegetation Map Units (1.0 – 34.0)	1,511	215	1,726	14,924.9	1,708.6	16,633.5	478.2	6,731.6	193.5
	Planted/Cultivated and Land Use/Land Cover Map Units (34.1 - 56.0)	250	85	335	3,674.7	1,641.3	5,316.0	209.4	2,151.4	84.8

*Refuge acres are based on LNWR Administrative boundary and include about 2190 acres of privately-owned inholdings (See Section **3.1**).

3.5 Accuracy Assessment

Of the 386 sampling points generated for the accuracy assessment, 39 were taken out of the analysis either because they were inaccessible in the field or had data inconsistencies (*i.e.* gps recording errors, missing species data, etc…). The remainders were evaluated for accuracy in September 2001. By comparing these points back to the vegetation map we were able to calculate an overall thematic accuracy of 77% for 38 vegetation map units. **Table 6** presents the accuracy assessment scores and confidence intervals for each map unit assessed along with the overall values.

Eleven map units were not assessed for accuracy due to their limited distribution and small size (usually below the minimum mapping unit) (see **Table 5**), these included:

4.0 Little Bluestem - (Sideoats Grama, Blue Grama) - Threadleaf Sedge Herbaceous Vegetation
11.0 Intermediate Wheatgrass Semi-Natural Herbaceous Vegetation
14.0 Canada Thistle - Weedy Forb Great Plains Herbaceous Vegetation (Provisional)
27.0 Western Snowberry Shrubland
28.0 American Plum Stands
30.0 Sandbar Willow / Mesic Graminoids Shrubland
31.0 American Hackberry Stands
32.0 Peachleaf Willow Woodland
33.0 Plains Cottonwood Woodland
34.0 Green Ash Stand
35.3 Native Species Plantings (Switchgrass)

In most cases these units represented very rare types that were already documented in their entirety by plot or observation data. Further, the small nature of these types made it impossible to place and buffer AA points within their polygons.

Using the Accuracy Assessment Contingency Table (**Table 6**)*:* The contingency table or error matrix is an array of numbers set out in rows and columns corresponding to a particular vegetation map unit relative to the actual vegetation type as verified on the ground. The column headings represent the vegetation associations as determined in the field and the row headings represent the map unit classes (codes) taken from the vegetation map (see **Table 5**). The highlighted diagonal indicates the number of points assessed in the field that agree with the map label. Conversely, the inaccuracies of each map unit are described as both errors of inclusion (user's or commission errors) and errors of exclusion (producer's or omission errors). By reading across this table (*i.e.* rows) one can calculate the percent error of commission, or how many polygons for each map unit were incorrectly labeled according to the field ecologist. By reading down the table (*i.e.* columns) one can calculate the percent error of omission, or how many polygons for that type were left off the map. Numbers "on the diagonal" tell the user how well the map unit was interpreted and how confident they can be in using it. Numbers "off the diagonal" yield important information about the deficiencies of the map including which types were often confused and which types were under or over represented.

Table 6. Contingency table (error matrix) for vegetation mapping at Lacreek National Wildlife Refuge.

	Map Class	1.0	2.1, 2.2	3.1	3.2	3.3	5.0	6.0	7.0	8.0	9.0	10.0	12.1-12.3	13.0	15.0	16.0	17.0	18.1	18.2	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.1	26.2	29.0	30.0	32.0	35.1	35.2	n/a*	Total Samples (N)	Commission Error % Correct	90% Confidence Interval -	90% Confidence Interval +
		Reference Data (Accuracy Assessment Field Classification)																																				
S	1.0	5																																	5	100%	62%	100%
a	2.1, 2.2		18		1												1																	1	21	86%	69%	95%
m	3.1			27	1																														28	96%	86%	100%
p	3.2				6																														6	100%	66%	100%
l	3.3					16											2																		18	89%	72%	98%
e	5.0						2		1																										3	67%	20%	97%
	6.0							7			1																								8	88%	58%	99%
D	7.0								8	1									1																10	80%	50%	95%
a	8.0								1	24	1								1	1												1			29	83%	70%	91%
t	9.0										30									6												1			37	81%	67%	91%
a	10.0									1		15																						1	17	88%	71%	97%
	12.1-12.3												7																					1	8	88%	68%	99%
(M	13.0													8						1	1							1		1	1		1		14	57%	36%	78%
a	15.0											3			4																				7	57%	28%	83%
p	16.0															2												1							3	67%	20%	97%
	17.0																5																		5	100%	62%	100%
U	18.1								2									1																1	4	25%	3%	68%
n	18.2								5	5									7	2								1							20	35%	20%	58%
i	19.0									1	1				2					15								2							21	71%	54%	87%
t)	20.0																				3														3	100%	46%	100%
	21.0																					0					1	3							4	0%	0%	50%
	22.0																						1												1	100%	10%	100%
	23.0																							3											3	100%	46%	100%
	24.0																			2					0										2	0%	0%	68%
	25.0																									4		1							5	80%	38%	98%
	26.1																										15	7							22	68%	50%	82%
	26.2																											19							19	100%	87%	100%
	29.0																											1	1						2	50%	5%	95%
	30.0																													1	1			2	4	25%	3%	68%
	32.0									1						1															3				5	60%	25%	89%
	35.1										1																					7			8	88%	58%	99%
	35.2				1																												2		3	67%	20%	97%
	n/a*				1																											1		n/a	2	n/a		
	Total Samples	5	18	27	10	16	2	7	17	33	34	18	7	8	6	3	8	1	9	27	4	0	1	3	0	4	16	36	1	2	5	10	3	6	Total Correct:		266	
Omission Error		100%	100%	100%	60%	100%	100%	100%	47%	73%	88%	83%	100%	100%	67%	67%	63%	100%	78%	56%	75%	0%	100%	100%	0%	100%	94%	53%	100%	50%	60%	70%	67%	n/a	Total Samples:		347	
90% Confidence -		62%	87%	91%	34%	87%	28%	68%	28%	59%	75%	65%	68%	75%	33%	20%	26%	10%	49%	37%	32%	0%	10%	46%	0%	50%	77%	38%	10%	5%	25%	35%	20%					
90% Confidence +		100%	100%	100%	81%	100%	100%	100%	71%	87%	96%	94%	100%	100%	91%	97%	85%	100%	94%	71%	97%	0%	100%	100%	0%	100%	99%	68%	100%	95%	89%	88%	97%					

OVERALL TOTAL ACCURACY = 77 % **OVERALL KAPPA INDEX = 76 %** [Pchance = 0.0551] **OVERALL TOTAL ACCURACY 90% UPPER AND LOWER CONFIDENCE INTERVAL: 81%** and **73%**

Map units 2.1 and 2.2 and 12.1, 12.2, and 12.3 were combined for the AA. The total sample size (N) is used to calculate Overall Total Accuracy. (Omission and Commission errors were calculated using total accuracy)

*n/a category represents land-use, semi-natural (i.e. disturbed, agricultural lands), or other types not included in the accuracy assessment.

For the purpose of the accuracy assessment, we combined map units 2.1 and 2.2 due to their complex intermixing and difficulty in distinguishing them apart on the ground. We also combined map units 12.1, 12.2, and 12.3 into one accuracy assessment class. These three units were mapped in the field by LNWR staff, not from aerial photography.

Of the assessed map units, some had lower then expected levels of accuracy. By carefully examining these discrepancies, we found four common issues that seem to explain most of the error. These include:

1. Many of the errors occurred when a polygon was mapped as an association that was very similar (*i.e.* same physiognomic class, same species, etc…), but different to the one identified by the field ecologist. This can happen because the photo interpreter and the field ecologist see the vegetation differently. For example, the photo interpreter may map large areas that have small inclusions of other types below the minimum mapping unit. However, a field biologist without an overhead perspective may deem them large enough to record as a separate type.

    - *Example:* Recording of inclusions likely explains the high omission error for Prairie Cordgrass – Sedge species Herbaceous Vegetation (Map Class 19.0). Prairie cordgrass is relatively easy to recognize in the field and typically occurs in mesic pockets such as shallow drainages and potholes. Some random AA points likely fell in these highly visible sites and were recorded as such even if they though were below the mmu.

2. Discrepancies with some map units likely arose from the NVCS classification system, which depends on an arbitrary cutoff of the dominant plant cover to separate associations with similar species. Further, some associations are recognized by the mere presence of diagnostic native species regardless of cover.

    - *Example:* Typically, the NVCS doesn't recognize an introduced or exotic plant community (semi-natural) until the cover of exotics reaches a high threshold (usually around 80%). At Lacreek, associations dominated by the exotics smooth brome, Kentucky bluegrass, or crested wheatgrass can, and will be recognized at a lower cover value even when associated with native species. We feel that the commission errors between native and semi-natural grassland associations as reported in Table 6 are likely a result of this high cut-off for classification.

3. The vegetation map was based on the photo interpretation of CIR aerial photography flown in 2000, while the accuracy assessment took place in 2001. Some map errors can be ascribed to changes in plant expression and phenology caused by differences in hydrologic and meteorological variation such as

moisture levels (wet vs. dry years) and land use and flooding regimes within the Refuge. Areas bordering Refuge pools are most likely to reflect this change since they are directly influenced by the timing, height, and duration of flooding or lack thereof. Vegetation in these areas are the most likely to exhibit variation from year to year and season to season.

- *Example:* Commission and omission errors for wetland associations such as Baltic Rush (21.0), Cattail types (26.1, 26.2) and others can likely be explained by hydrologic variation from year to year. Areas that dried out in 2001 would likely not be recorded as the same wetland type leading to errors of commission. We feel this explains the high commission error separating semipermanently flooded (26.1) from seasonally flooded cattails (26.2). (Conversely, areas that were wet in 2001 but not in 2000 would lead to errors of omission.)

4. Subtle differences in grassland types were extremely hard to distinguish from the aerial photography. This was further compounded by the Refuges need to have seeding history included for sites that were reclaimed or planted with native species.

- *Example:* Commission errors for Saltgrass and Foxtail Herbaceous Vegetation types (18.1 and 18.2) were primarily confused with other grassland types including Western wheatgrass (7.0), Kentucky bluegrass (8.0), and Prairie cordgrass (19.0). Although they appear to be different types, we found that most of the diagnostic species tended to occur across all types. This species overlap likely led to difficult AA determinations in the field and commission error.

3.6 Recommendations for Future Projects

Several ideas for improving the mapping process have surfaced as a result of the Lacreek project. Improving the mapping process in ways suggested herein would increase quality and efficiency, and provide for more accurate and useful products.

Vegetation Classification and Characterization

Lacreek National Wildlife Refuge lies within the Northwestern Great Plains ecoregion and includes biological elements typical of the Keya Paya Tablelands and Nebraska Sandhills sections. In addition, the Refuge is intensively managed for wildlife through control of exotics such as Canada thistle, water storage and release for fish and birds, and seeding areas for forage. This variation due to changes in geology, topography, and land management creates a mosaic of plant species in numerous and sometimes atypical assemblages. Identifying these associations and placing them in the NVCS for LNWR was extremely challenging, time-consuming and in most cases not overly beneficial to management needs. Instead, alternative classifications such as land-cover or land-history types for manipulated and actively managed sites and NVCS for pristine areas may have made more sense.

Regardless of the classification used, we highly recommend that a complete (or nearly completed) classification be in place before the actual interpretation begins. Plot sampling should begin early in the project, followed by analysis of the vegetation data to the NVCS before the ground-truthing and interpretation of the aerial photographs. It is important to have written descriptions of the associations, approval of the types by the Refuge, and a vegetation key during ground-truthing so that vegetation types can be related to the photo signatures. Also critical is deciding how to characterize and describe vegetation that has been manipulated in the past. This includes dealing with areas inherent to Refuges that have been reclaimed or reseeded and are not necessarily covered by the NVCS.

Vegetation Mapping

During the drier-than-normal 2000 field season when the aerial photographs were taken and when most of the fieldwork was conducted, cool season grassland species were the principal species expressed. In contrast, during the 2001 field season, when the accuracy assessment was conducted, relatively large amounts of summer precipitation shifted the vegetative expression to warm season species. The difference in vegetative expression between 2000 and 2001 was a factor during the accuracy assessment, but was not during the photo interpretation process. This inconsistency was realized in lower than expected map class accuracies and should probably be addressed in future grassland projects. Possible solutions include multiple aerial photo missions in both cool (dry) and warm (wet) seasons, or recognition of this shift by the accuracy assessment team.

Central to the mapping process is the ability to produce a clearly defined set of map units. Ideally, these will be based entirely from the NVCS on a strict one-to-one correspondence, but typically they involve the use of detailed links or crosswalks. Normally, crosswalks help clarify the differences between vegetation characteristics that can be seen on aerial photography and those evident on the ground. However, crosswalks between the map units and NVCS associations at LNWR were relatively confusing and lengthy. This was due in part to the difficult task of describing the manipulated and semi-natural vegetation inherit, not only to Lacreek, but all refuges. In order to avoid having to describe and map both NVCS and local management types, standard-mapping units should be created for managed USFWS lands in addition to the NVCS. These would include such things as reseeded and reclaimed fields, highly manipulated wetlands, weedy mudflats, etc. Having a standard list of management vegetation types would eliminate the need for elaborate crosswalks and would greatly promote increased sharing, exchanging, and comparing of vegetation-related data across all refuges. At LNWR, having these map units decided beforehand would have saved untold time spent re-interpreting, revising, re-mapping, and creating crosswalks for managed areas.

Summary

Recognizing the logistical and technical issues inherent to the vegetation mapping process, there are a number of factors that are critical to the success of any vegetation-mapping project. The timing associated with collecting aerial photography and conducting fieldwork are essential first steps. The photography for LNWR was taken at the end of July while the initial fieldwork was conducted in mid-September. Simultaneously completing this portion of the process in late June or early July would have greatly enhanced both photo interpretation and vegetation classification.

The amount of time needed to develop map units, create mapping conventions, make photo interpretation decisions, and produce the final digital map is inversely proportional to the degree that the parties involved communicate. Consensus building and good communication among the ecologists, photo interpreters, and Refuge staff greatly increases the quality and efficiency of the project. Future projects should strive to involve USFWS staff (both at the region and local levels), NatureServe ecologists, and BOR ecologists/photo-interpreters at all stages of the project. Prompt and constructive feedback from Refuge personnel throughout, but especially during the initial interpretation and classification can substantially reduce many of the problems that might otherwise surface late in the process.

It was also noted by USFWS staff that 80% accuracy for every map unit might not be realistic or desirable for vegetation mapping projects in refuges. Having less than 80% accuracy for some classes is likely a result of either land manipulation and/or seasonal/annual variations in precipitation, flooding, draw down timing etc. Instead of grouping similar types together to increase the overall accuracy it was deemed more

important to retain the detail for future studies. This detail will allow the refuge staff to focus their validation/ground-truthing efforts along with their long-term monitoring and inventory studies on types that are subject to anthropogenic or natural environmental change.

Pelicans at Lacreek National Wildlife Refuge

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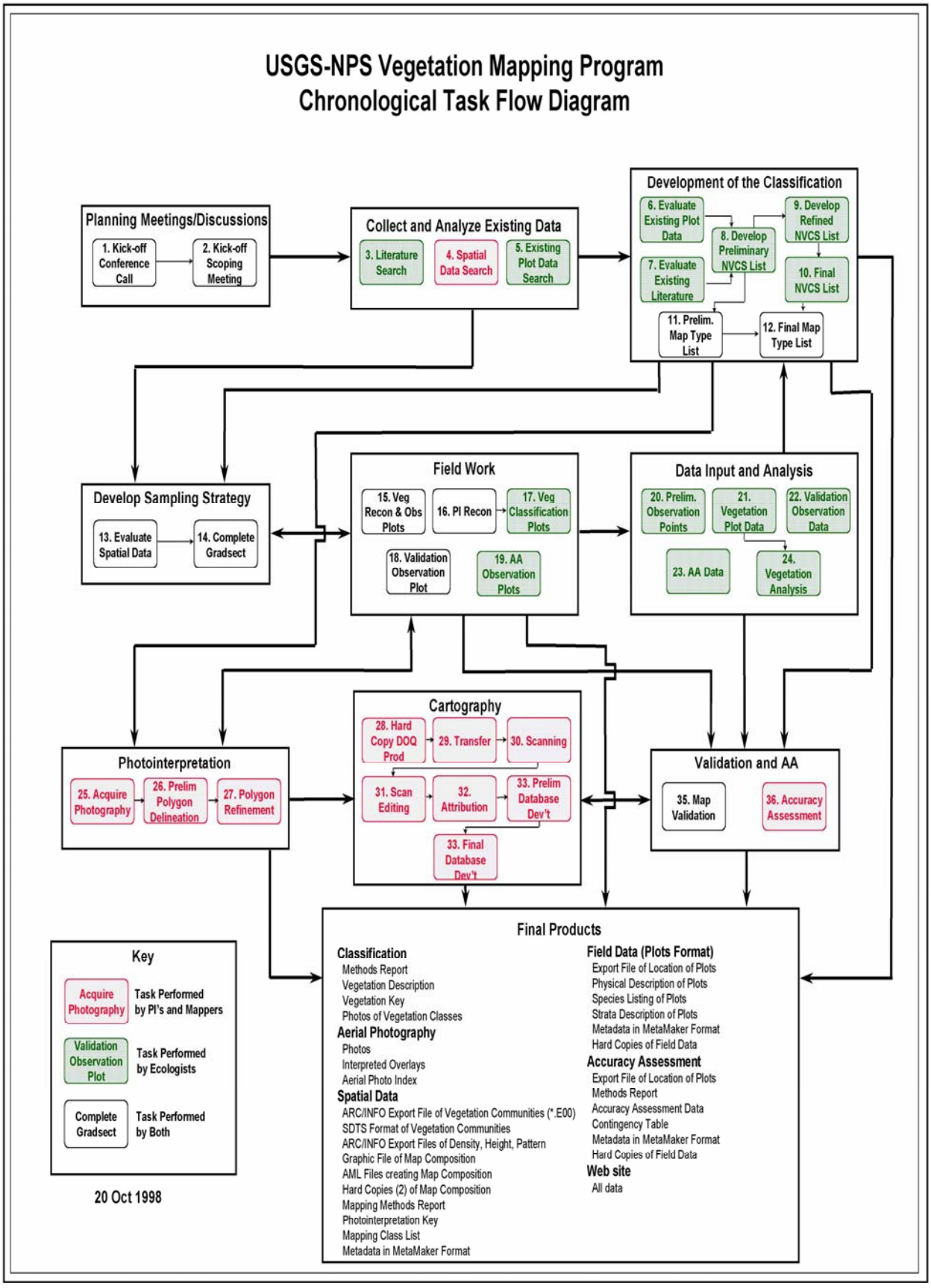
APPENDIX A: Flowchart for the USGS-NPS Vegetation Mapping Program

(Tom Owens, USGS-BRD)

(The following diagram is included to illustrate the different stages and how they are interconnected in the NPS vegetation mapping program. Mapping vegetation on National Wildlife Refuges may not include all the steps listed below or additional stages specific to USFWS concerns may not be included. Please see the material and methods section of this report for more information.)


USGS-NPS Vegetation Mapping Program
Chronological Task Flow Diagram
Planning Meetings/Discussions
1. Kick-off Conference Call
2. Kick-off Scoping Meeting
Collect and Analyze Existing Data
3. Literature Search
4. Spatial Data Search
5. Existing Plot Data Search
Development of the Classification
6. Evaluate Existing Plot Data
7. Evaluate Existing Literature
8. Develop Preliminary NVCS List
9. Develop Refined NVCS List
10. Final NVCS List
11. Prelim. Map Type List
12. Final Map Type List
Develop Sampling Strategy
13. Evaluate Spatial Data
14. Complete Gradsect
Field Work
15. Veg Recon & Obs Plots
16. PI Recon
17. Veg Classification Plots
18. Validation Observation Plot
19. AA Observation Plots
Data Input and Analysis
20. Prelim. Observation Points
21. Vegetation Plot Data
22. Validation Observation Data
23. AA Data
24. Vegetation Analysis
Photointerpretation
25. Acquire Photography
26. Prelim Polygon Delineation
27. Polygon Refinement
Cartography
28. Hard Copy DOQ Prod
29. Transfer
30. Scanning
31. Scan Editing
32. Attribution
33. Prelim Database Dev't
33. Final Database Dev't
Validation and AA
35. Map Validation
36. Accuracy Assessment
Key
Acquire Photography
Task Performed by PI's and Mappers
Validation Observation Plot
Task Performed by Ecologists
Complete Gradsect
Task Performed by Both
20 Oct 1998
Final Products
Classification
Methods Report
Vegetation Description
Vegetation Key
Photos of Vegetation Classes
Aerial Photography
Photos
Interpreted Overlays
Aerial Photo Index
Spatial Data
ARC/INFO Export File of Vegetation Communities (*.E00)
SDTS Format of Vegetation Communities
ARC/INFO Export Files of Density, Height, Pattern
Graphic File of Map Composition
AML Files creating Map Composition
Hard Copies (2) of Map Composition
Mapping Methods Report
Photointerpretation Key
Mapping Class List
Metadata in MetaMaker Format
Field Data (Plots Format)
Export File of Location of Plots
Physical Description of Plots
Species Listing of Plots
Strata Description of Plots
Metadata in MetaMaker Format
Hard Copies of Field Data
Accuracy Assessment
Export File of Location of Plots
Methods Report
Accuracy Assessment Data
Contingency Table
Metadata in MetaMaker Format
Hard Copies of Field Data
Web site
All data

APPENDIX B: Work Proposal (USBR-RSGIS)

Proposal for Classifying and Mapping Vegetation Communities Lacreek National Wildlife Refuge - South Dakota

April 27, 2000

U.S. Bureau of Reclamation, Remote Sensing and Geographic Information Group
Technical Service Center, Denver, Colorado

1. Overview

This document presents our revised proposed methods and estimated costs associated with classifying and mapping vegetation communities at Lacreek National Wildlife Refuge (LNWR), SD to the standards developed under the USGS-NPS Vegetation Mapping Program. This discussion is based on our previous proposal and from discussions during our meeting with the FWS the morning of April 27th. The area to be mapped will be approximately 18,400 acres inside the LNWR including some adjacent or interior private lands. If access to the non-LNWR areas cannot be arranged, we would anticipate not doing any field work in these areas, therefore, the accuracy assessment would only apply to LNWR lands. According to the FWS, the Refuge consists of 16,136 acres with 2300 acres of open water.

(Note, refer to Section 5. below for abbreviations used in this proposal.)

2. Aerial Photograph Acquisition and Basemap.

The FWS will acquire the necessary CIR photography for this project. Also, B/W DOQQ's of this area are available and will also be acquired by the FWS. The date of the DOQQ's is 1991, which means that there will be a 9-year difference between sets of photography. Depending on the amount of changes occurring at the Refuge during this time period, this may result in some difficulty during the GIS transfer stage (3.5 below). The FWS should contact the Refuge to find out if this time difference might be a problem. Also, this process will not result in a digital version of the CIR photography. If a digital version is desired, the CIR photos would have to be scanned. However, our proposal does not include costs for scanning the CIR photos.

3. Project Tasks.

3.1 Scoping / Kick-off Meeting.

A preliminary meeting would be required with Refuge and Regional FWS personnel to discuss the project, present examples of similar projects the BOR has performed, and acquire available information from the FWS (ex: Refuge boundary, roads, hydrology, NWI, etc). This meeting would allow FWS to address any special mapping needs and vegetation classification. Our proposal is based on this meeting taking place in Denver, therefore, no field time or travel expenses are anticipated for this task.

3.2. Field Data Collection.

Vegetation field data will be collected at two levels of intensity: 1) Approximately 75 observation points will be visited and data collected to determine the range of aerial photograph signatures to guide interpretation for potential map classes or units, collect preliminary vegetation data relative to species dominance and habitat structure, and to determine the distribution of plant associations within LNWR; and 2) More detailed plot data (vegetation, soils, hydrology, environmental, etc.) will be collected for each plant association present to determine the NVCS classification. A set of representative color slides or digital photographs for each plant association and a comprehensive species list will be produced.

Detailed vegetation data and photo-documentation will be collected from 1-3 plots per association (approximately 50-75 vegetation plots), depending on stand dominance and variability within the landscape. Likely plant associations will include stand dominants such as eastern cottonwood, green ash, willow (peachleaf and sandbar/coyote), western snowberry/ buckbrush, chokecherry, soapweed yucca, silver and sand sagebrush, silver buffaloberry, little bluestem, western wheatgrass, prairie sand-reed, blue grama, prairie cordgrass, cattail, bulrush, spikerush, sedge, reed canarygrass, common reed, smooth brome, Kentucky bluegrass, and intermediate wheatgrass, among others. Other classes may include blowouts and prairie dog colonies. Plots will be established in representative vegetation stands that meet or exceed the minimum mapping unit (mmu) of 0.5 hectares. If determined to be important to Refuge staff, some smaller units of vegetation or land use may be considered as "Refuge Specials", to be determined during scoping meetings. Unless otherwise directed by FWS-LNWR ecologists/staff, the plots will be 10m x 10m for herbaceous and shrub associations and 20m x 20m for woodlands. During the Observation data collection field trip, a PI reconnaissance will also take place (see item 3.4 below).

Observation Point/Photo Signature Data Collection

- 2 Researchers/2 Travel days/5 data collection/recon days = 14 field days (Summer 2000).

Plot/NVCS Classification Data Collection

- 2 Researchers/2 Travel Days/10 data collection days = 20 field days (Summer 2000).

1 Researcher/1 day per trip planning = 2 office days (ASAP)

3.3. Vegetation Classification.

Plot data collected in LNWR will be evaluated using the NVCS (Standardized National Vegetation Classification System); this system contains seven classification levels with the two finest being the alliance and association (community) levels. These data are quantitatively analyzed using ordination techniques (Detrended Correspondence Analysis and Non-Metric Multidimensional Scales), a clustering algorithm, Unweighted Pair-Group Method Using Arithmetic Means, and Two-Way Indicator Species Analysis.

Following analysis, plant associations are described as they occur in LNWR (local description), and nationally or world-wide (global descriptions, by others). Further, a dichotomous key to the

plant associations is prepared and illustrated with photos taken during the vegetation data gathering phase of the study. This key is valuable both to researchers conducting the accuracy assessment for this project, but also as an educational guide for other researchers or visitors to LNWR. Another product of this analysis is a comprehensive species list.

Vegetation Data Analysis/Descriptions/Species List: 1 Researcher/20 office days

3.4. Photo-interpretation.

A reconnaissance trip to establish photo-signatures and take ground photographs will be conducted prior to photo-interpretation. This trip will be combined with the Field Data Collection trip (see 3.2 above) and will add one day to that trip. Interpretation of the aerial photos will be performed using a combination of stereo pairs and on-screen digitizing. Data will be interpreted on drafting film (Mylar) overlays on the hardcopy orthophoto prints.

Photo-interpretation: 1 Researcher / 16 days = 16 office days

3.5. GIS Database.

Mylar overlays from the photo-interpretation will be scanned, rectified, and converted to ArcInfo coverages. The transfer technique will involve finding common control points between the DOQQ's and the CIR prints and then transforming and adjusting the scanned linework using ArcInfo software. This is a timely process, may prove to be difficult due to the 9-year time difference in photography, and will not result in a truly ortho-rectified database (as opposed to using ortho-rectified CIR photos). Coverages will be edited, attributed according to the markings on the mylar overlays, and combined into one final coverage. One overall hard-copy map will be produced. An FGDC-compliant metadata file will be produced for the coverage and the field data points.

Transfer data into GIS database: 1 Technician / 20 days = 20 office days

Produce Map Product: 1 Technician / 2 days = 2 office days

Metadata: 1 Technician / 2 days = 2 office days

3.6. Accuracy Assessment.

An accuracy assessment (AA) of the vegetation map will be performed during the second field season, Summer 2001. Eighty to 100 points will be randomly selected and field ecologists will navigate to their coordinates using a hand-held GPS receiver and determine the vegetation type present. The vegetation type will be determined by using an *Illustrated Field Key to the NVCS Vegetation Associations at LNWR*, prepared for this purpose. Also recorded will be other vegetation types occurring within 50m of the selected point. This data will be entered into a digital overlay (also export file for AA plot locations) for the vegetation map and each point will be evaluated for accuracy or error of omission or commission; an AA matrix or contingency table will be prepared to summarize results.

Typical guidelines for the AA procedure include:

1. Observations of vegetation types are ground-based,
2. Ground sampling techniques are similar to the Observation Points collected during initial classification,
3. The number of samples per vegetation mapping unit will vary depending on abundance of the class upon the landscape,
4. Logistical planning for the AA will revolve around access to work areas within LNWR and will be based on completed vegetation maps, and
5. AA points will be randomly selected.

Following the AA, a decision analysis will be undertaken which examines the accuracy of each vegetation-mapping unit. The analysis will determine if the vegetation mapping unit, with its inherent variability: 1) meets the minimum standard of 80% accurate at the 90% confidence interval and is considered acceptable, or 2) two or more vegetation mapping units must be combined into an alliance, complex, or mosaic in order to meet the minimum accuracy standard.

- 2 Researchers/2 Travel days/3 data collection days = 10 field days (Summer 2001).
- 2 Researchers/3 Office days/ = 6 office days (Summer 2001).

3.7. Final Report

All study methods, results, and appendices will be presented in a comprehensive final report. At a minimum, the final report will contain: list of contacts and contributors, list of tables and figures, executive summary and introduction, project area description, materials and methods, results, discussion, bibliography, appendices, CD-ROM (containing report and digital point and vegetation coverages in Arc export format), and a vegetation map. Along with the final report, all original observation point/plot/accuracy assessment data will become the property of FWS as will any plant materials collected and preserved for identification purposes.

- Final Report: 2 Researchers/10 office days = 20 days (Late Summer 2001).

4. Cost Estimates. - (Please contact BOR RSGIG for information on the cost estimate).

5. Abbreviations and Acronyms:

B/W	Black and White; CIR Color-Infrared ;
DOQQ	Digital Orthophoto Quarter Quadrangle (USGS product);
FGDC	Federal Geographic Data Committee;
FWS	U.S. Fish and Wildlife Service;
Metadata	Describes the content, quality, condition, and other characteristics of data;
NAPP	National Aerial Photography Program;
NPS	National Park Service;
LNWR	Lacreek National Wildlife Refuge;

APPENDIX C: Observation, Plot, and AA Field Forms

NATIONAL WILDLIFE REFUGE VEGETATION MAPPING PROGRAM: OBSERVATION POINT FORM (1997)

IDENTIFIERS/LOCATORS

Plot Code_____ Polygon Code_____

Provisional Community Name___ _____

State ___ Refuge Name _____ Refuge Site Name _____

Quad Name_____ Quad Code_____

GPS file name_____ Field UTM X___ ___ ___ ___ ___ ___ m E Field UTM Y___ ___ ___ ___ ___ ___ ___ m N

please do not complete the following information when in the field
Corrected UTM X___ ___ ___ ___ ___ ___ m E Corrected UTM Y___ ___ ___ ___ ___ ___ ___ m N UTM Zone_____

Survey Date_____ Surveyors_____

ENVIRONMENTAL DESCRIPTION

Elevation _____ Slope _____ Aspect_____

Topographic Position

Landform

Cowardian System	Hydrologic Regime		Salinity Modifiers
___Upland	Non-Tidal		___Saltwater
___Riverine	___Permanently Flooded	___Saturated	___Brackish
___Palustrine	___Semipermanetly Flooded	___Temporarily Flooded/Saturated	___Freshwater
___Lacustrine	___Seasonally Flooded	___Intermittently Flooded	

Environmental Comments:	Unvegetated Surface: (please use the cover scale below) ___ Bedrock ___ Litter, duff ___ Wood (> 1 cm) ___ Large rocks (cobbles, boulders > 10 cm) ___ Small rocks (gravel, 0.2-10 cm) ___ Sand (0.1-2 mm) ___ Bare soil ___ Other:_____

VEGETATION DESCRIPTION

Leaf phenology (of dominant stratum)	Leaf Type (of dominant stratum)	Physiognomic class	Cover Scale for Strata & Unvegetated Surface	Height Scale for Strata
Trees and Shrubs ___Evergreen ___Cold-deciduous ___Drought-deciduous ___Mixed evergreen - cold-deciduous ___Mixed evergreen - drought-deciduous Herbs ___Annual ___Perennial	___Broad-leaved ___Needle-leaved ___Mixed broad-leaved/Needle leaved ___Microphyllous ___Graminoid ___Forb ___Pteridophyte	___Forest ___Woodland ___Shrubland ___Dwarf Shrubland ___Herbaceous ___Nonvascular ___Sparsely Vegetated	01 5% 02 10% 03 20% 04 30% 05 40% 06 50% 07 60% 08 70% 09 80% 10 90% 11 100%	01 <0.5 m 02 0.5-1m 03 1-2 m 04 2-5 m 05 5-10 m 06 10-15 m 07 15-20 m 08 20-35 m 09 35 - 50 m 10 >50 m

Strata	Height	Cover Class	Dominant species (mark any known diagnostic species with a *)	Cover Class
T1 Emergent	_____	_____		
T2 Canopy	_____	_____		
T3 Sub-canopy	_____	_____		
S1 Tall shrub	_____	_____		
S2 Short Shrub	_____	_____		
S3 Dwarf-shrub H Herbaceous	_____	_____		
N Non-vascular	_____	_____		
V Vine/liana	_____	_____		
E Epiphyte	_____	_____		

please see the table on the previous page for height and cover scales for strata

Other Comments

Cover Scale for Species
01 <1%
02 1-5%
03 5-25%
04 25-50%
05 50-75%
06 75-100%

NATIONAL PARK VEGETATION MAPPING PROGRAM: PLOT SURVEY FORM

IDENTIFIERS/LOCATORS

Plot Code____LACREEK_____ Habitat/BPU Code_____

Provisional Community Name_____

State _SD__ Park Name__Lacreek NWR_____ Refuge Site Name_____

Quad Name_____ Quad Code_____

GPS file name_____ Field UTM X___ ___ ___ ___ ___ ___ m E Field UTM Y___ ___ ___ ___ ___ ___ ___ m N

Comments: _____ Error +/- ___ ___ m

Please do not complete the following information when in the field

Corrected UTM X___ ___ ___ ___ ___ ___ m E Corrected UTM Y___ ___ ___ ___ ___ ___ ___ m N UTM Zone _____

Survey Date_____ Surveyors_____

Directions to Plot

Plot length(m)_____ Azimuth _____ Plot width(m)_____ If circle (diam)_____ Plot Photos (y/n) __ Roll # _____ Frame # _____

Plot Permanent (y/n) ____ Comments on photos or marker

Plot representativeness (discuss decisions for placement and/or reasons for non-representativeness)

a. Representativeness of association (if known):

b. Representativeness of plot in stand:

ENVIRONMENTAL DESCRIPTION

Elevation _____ Slope _____ Aspect_____

Topographic Position (see cheat sheet)

Landform (see cheat sheet)

Surficial Geology (see cheat sheet)

Cowardian System

___ Upland ____ Palustrine

___ Riverine ____ Lacustrine

Hydrology

___Permanently Flooded ___Seasonally Flooded ___Temporarily Flooded

___Semipermanetly Flooded ___Saturated ___Intermittently Flooded

___Unknown

Environmental Comments (dynamic stage, fire history, insect damage, etc):

Ground Cover: *(please estimate to the nearest percentage. Sum = 100%)*

___ Bare soil ___ Litter / duff ___ Wood (> 1 cm)

___ Bedrock ___Large rocks (cobbles, boulders > 10 cm)

___ Small rocks (gravel, 0.2-10 cm) ___ Sand (0.1-2 mm) dune /alluvium

___ Moss ___ Lichen ___ Cryptogam ___ Water ___ Other (name):

Soil Texture:

___ sand ___ loamy sand ___ sandy loam ___ loam

___ silt loam ___ silt ___ clay loam ___ silty clay

___ sandy clay ___ clay ___ peat ___ muck

Soil Drainage

___ Rapidly drained ___ Well drained

___ Moderately well drained ___ Somewhat poorly drained

___ Poorly drained ___ Very poorly drained

VEGETATION DESCRIPTION

Leaf phenology (of dominant stratum)	Leaf Type (of dominant stratum)	Physiognomic class	Cover Scale for Strata	Height Scale for Strata
Trees and Shrubs __Evergreen __Cold-deciduous __Mixed evergreen-cold-deciduous Herbs ___Annual ___Perennial	___Broad-leaved ___Needle-leaved ___Microphyllous ___Graminoid ___Forb ___Pteridophyte	___Forest ___Woodland ___Shrubland ___Dwarf Shrubland ___Herbaceous ___Nonvascular ___Sparsely Vegetated	T 0-1% P >1-5% 1 >5-15% 2 >15-25% 3 >25-35% 4 >35-45% 5 >45-55% 6 >55-65% 7 >65-75% 8 >75-85% 9 >85-95% 10 > 95%	01 <0.5 m 02 0.5-1m 03 1-2 m 04 2-5 m 05 5-10 m 06 10-15 m 07 15-20 m 08 20-35 m 09 35 – 50 m 10 >50 m

	Height/Strata Class	Cover Class	Dominant Species (mark Diagnostics with *)
T1 Emergent			
T2 Canopy			
T3 Sub-canopy			
S1 Tall shrub			
S2 Short Shrub			
S3 Dwarf-shrub			
Ht Herbaceous			
H1 Graminoids			
H2 Forbs			
H3 Ferns			
H4 Tree seedlings			
N Non-vascular			
V Vine/liana			
E Epiphyte			

Animal Use Evidence (including scat, browse, graze, burrows, bedding sites, etc)

Natural and Anthropogenic Disturbance Comments (please see cheat sheet for impact codes, list intensity as High, Med, or Low)

Other Comments (locations of photos and permanent plot marker)

Lacreek National Wildlife Refuge Vegetation Mapping Project

Plot Code__Lacreek._____

Species/percent cover: Starting with the uppermost stratum, list all species with % cover for each species in the stratum. For each tree species estimate seedling, sapling, mature and total cover indicating stratum . Also for forests and woodlands, on a separate page **or** line below each tree species, list the DBH of all trees above 5 cm diameter. Separate measurements with a comma (note if measurements are from multi-stemmed tree). Put an asterisk next to any species that are known diagnostics for a particular community in the classification. **Also list species outside the plot at the end of the table or designate with a 0 in Cover Class column.**

Stratum	Species Name	Cover Class	Stratum	Species Name	Cover Class	Stratum	Species Name	Cover Class

Cover Class Scale

T = >0-1%	5 = >45-55%
P = >1-5%	6 = >55-65%
1 = >5-15%	7 = >65-75%
2 = >15-25%	8 = >75-85%
3 = >25-35%	9 = >85-95%
4 = >35-45%	10 = >95%

Tree D.B.H Form

Plot Code: Lacreek Units in cm or inches (circle one)

Record tree diameter over 5 cm at 4.5 feet (1.37 m) height for species that contribute to tree canopy.

Separate measurements of multi-stemmed trees with commas. Can estimate by 5 cm dia. classes

Species	D.B.H.(s) for multi-stems trees

Species	D.B.H.(s) for multi-stems trees

Accuracy assessment Form (1998)
USGS-USFWS Vegetation Mapping Program

1. Plot Number _____ 2. Refuge Code _____ 3. Date _____

4. Observer(s)_____5. Datum _____ 6. Accuracy _____

7. UTM Coordinates: Easting __ __ __, __ __ __ Northing __, __ __ __, __ __ __

8. UTM Zone _____ 9. Offset from Point: Easting _____m Northing _____m

10. Topographic Description _____

11. Elevation _____m 12. Aspect _____

13. Veg Assoc. at Site _____

14. Veg Assoc 2 within 50m of Site _____

15. Veg Assoc 3 within 50m of Site _____

16. Major Species Present (by strata)_____

_____

_

_____

_

17. Canopy Closure of Top Layer _____

18. Rationale for Classification_____

_____

_____

_____

19. Comments _____

_____

_____

APPENDIX F: A List of Species found at Lacreek National Wildlife Refuge

Summarized by Plant Family
Nomenclature follows the PLANTS database

The following list of species includes those found during the Vegetation Mapping Project for Lacreek National Wildlife Refuge. It is not intended to be a comprehensive list of every species that occurs at LNWR. Species are presented alphabetically by family.

Family	Scientific Name	Common Name
Agavaceae	*Yucca glauca Nutt.*	small soapweed yucca
Alismataceae	*Sagittaria latifolia Willd.*	broadleaf arrowhead
Apocynaceae	*Apocynum cannabinum L.*	Indianhemp
Asclepiadaceae	*Asclepias pumila (Gray) Vail*	plains milkweed
	Asclepias speciosa Torr.	showy milkweed
Asteraceae	*Ambrosia psilostachya DC.*	Cuman ragweed
	Artemisia dracunculus L.	green sagewort
	Artemisia ludoviciana Nutt.	Louisiana sagewort
	Aster ericoides L.	heath aster
	Bidens cernua L.	nodding beggartick
	Carduus nutans L.	nodding plumeless thistle
	Cirsium arvense (L.) Scop.	Canada thistle
	Cirsium undulatum (Nutt.) Spreng.	wavyleaf thistle
	Dyssodia papposa (Vent.) A.S. Hitchc.	fetid marigold
	Eupatorium maculatum L.	spotted joepyeweed
	Helianthus annuus L.	common sunflower
	Helianthus grosseserratus Martens	sawtooth sunflower
	Heterotheca villosa (Pursh) Nutt. ex DC.	golden aster
	Lactuca serriola L.	prickly lettuce
	Liatris punctata Hook.	dotted gayfeather
	Lygodesmia juncea (Pursh) D. Don ex Hook.	rush skeletonplant
	Oligoneuron rigidum (L.) Small	rigid goldenrod
	Senecio L.	groundsel
	Solidago canadensis L.	Canada goldenrod
	Solidago gigantea Ait.	giant goldenrod
	Solidago missouriensis Nutt.	Missouri goldenrod
	Solidago mollis Bartl.	velvety goldenrod

	Sonchus arvensis L.	field sowthistle
	Tragopogon dubius Scop.	yellow salsify
Boraginaceae	*Lappula occidentalis (S.Wats) Greene*	beggar's tick
Cactaceae	*Opuntia polyacantha Haw.*	plains pricklypear
Caprifoliaceae	*Symphoricarpos occidentalis Hook.*	western snowberry
Chenopodiaceae	*Chenopodium L.*	
	Chenopodium album L.	lambsquarters
	Kochia scoparia (L.) Schrad.	common kochia
Convolvulaceae	*Convolvulus arvensis L.*	field bindweed
	Ipomoea leptophylla Torr.	bush morningglory
Cyperaceae	*Carex L.*	sedge
	Carex filifolia Nutt.	threadleaf sedge
	Carex inops Bailey	longstolon sedge
	Carex inops ssp. heliophila (Mackenzie) Crins	sun sedge
	Carex nebrascensis Dewey	Nebraska sedge
	Carex pensylvanica Lam.	Pennsylvania sedge
	Cyperus L.	flatsedge
	Eleocharis R. Br.	spikerush
	Schoenoplectus pungens (Vahl) Palla	threesquare bulrush
	Schoenoplectus acutus (Muhl. Ex Bigelow)	hardstem bulrush
Elaeagnaceae	*Elaeagnus angustifolia L.*	Russian olive
Euphorbiaceae	*Croton L.*	croton
	Chamaesyce serpyllifolia (pers.) Small	thyme-leaved Spurge
Fabaceae	*Amorpha canescens Pursh*	leadplant
	Astragalus L.	milkvetch
	Glycyrrhiza lepidota Pursh	American licorice
	Medicago sativa L.	alfalfa

	Melilotus alba Medikus	white sweetclover
	Melilotus officinalis (L.) Lam.	yellow sweetclover
	Petalostemon albidus (Torr. & Gray) Small	white prairieclover
	Petalostemon purpureus (Vent.) Rydb.	purple prairie clover
	Psoralea argophylla Pursh	silverleaf scurfpea
	Psoralea tenuiflora Pursh	wild alfalfa or scurfpea
Juncaceae	*Juncus balticus Willd.*	Baltic rush
	Juncus dudleyi Wieg.	Dudley's rush
Lamiaceae	*Lycopus americanus Muhl. ex W. Bart.*	American waterhorehound
Lamiaceae	*Mentha arvensis L.*	wild mint
Linaceae	*Linum L.*	flax
Onagraceae	*Gaura coccinea Nutt. ex Pursh*	scarlet beeblossom
	Oenothera serrulata Nutt.	yellow sundrop
Poaceae	*Agropyron Gaertn.*	wheatgrass
	Agropyron cristatum (L.) Gaertn.	crested wheatgrass
	Thinopyrum intermedium (Host) Beauv.	intermediate wheatgrass
	Andropogon gerardii Vitman	big bluestem
	Andropogon hallii Hack.	sand bluestem
	Aristida purpurea Nutt.	purple threeawn
	Bouteloua curtipendula (Michx.) Torr.	sideoats grama
	Bouteloua gracilis (Willd. ex Kunth) Lag. ex Griffiths	blue grama
	Bouteloua hirsuta Lag.	hairy grama
	Bromus inermis Leyss.	smooth brome
	Bromus japonicus Thunb. ex Murr.	Japanese brome
	Bromus tectorum L.	cheatgrass
	Calamagrostis inexpansa Gray	reed bent-grass
	Calamovilfa longifolia (Hook.) Scribn.	prairie sandreed
	Dichanthelium wilcoxianum (Vasey) Freckmann	fall panicum

	Distichlis spicata (L.) Greene	inland saltgrass
	Echinochloa crus-galli (L.) Beauv.	barnyardgrass
	Hordeum jubatum L.	foxtail barley
	Koeleria macrantha (Ledeb.) J.A. Schultes	prairie Junegrass
	Muhlenbergia Schreb.	
	Muhlenbergia asperifolia (Nees & Meyen ex Trin.) Parodi	alkali muhly
	Nassella viridula (Trin.) Barkworth	green needlegrass
	Panicum L.	panicum
	Panicum capillare L.	witchgrass
	Panicum virgatum L.	switchgrass
	Panicum virgatum var. cubense Griseb.	switchgrass
	Pascopyrum smithii (Rydb.) A. Love	western wheatgrass
	Phleum pratense L.	timothy
	Phragmites australis (Cav.) Trin. ex Steud.	common reed
	Poa compressa L.	Canada bluegrass
	Poa pratensis L.	Kentucky bluegrass
	Schizachyrium scoparium (Michx.) Nash	little bluestem
	Setaria viridis (L.) Beauv.	green bristlegrass
	Sorghastrum nutans (L.) Nash	yellow Indiangrass
	Sorghum halepense (L.) Pers.	Johnsongrass
	Spartina pectinata Link	prairie cordgrass
	Sporobolus airoides (Torr.) Torr.	alkali sacaton
	Sporobolus cryptandrus (Torr.) Gray	sand dropseed
	Hesperostipa comata (Trin&Rupr)Barkwirth	needle-and-thread
Polygonaceae	*Polygonum amphibium L.*	water knotweed
	Rumex crispus L.	curly dock
Rosaceae	*Prunus pumila L.*	sand cherry
	Rosa arkansana Porter	prairie rose

Salicaceae	*Populus deltoides Bartr. ex Marsh.*	eastern cottonwood
Salicaceae	*Salix amygdaloides Anderss.*	peachleaf willow
Salicaceae	*Salix exigua Nutt.*	sandbar willow
Solanaceae	*Solanum L.*	nightshade
Typhaceae	*Typha L.*	cattail
Verbenaceae	*Verbena hastata L.*	swamp verbena
	Unknown Fern	